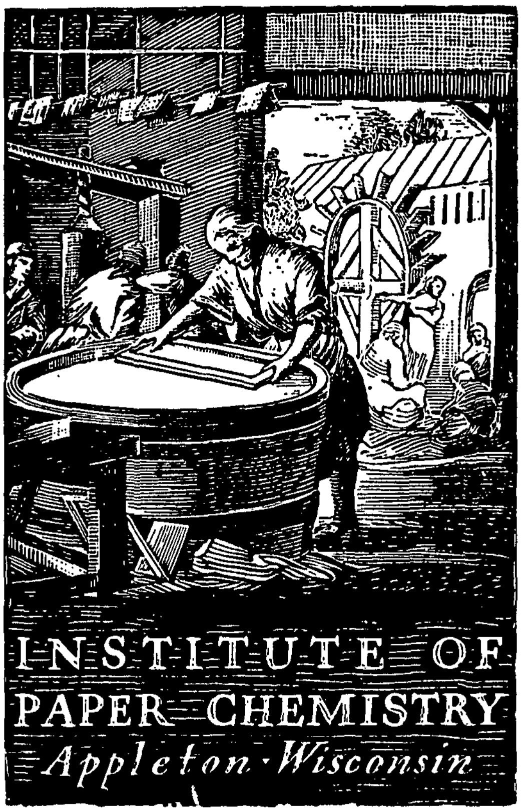

WATER RECYCLE SYSTEM SIMULATION

Project 3251

Report One

A Progress Report

to

MEMBERS OF THE INSTITUTE OF PAPER CHEMISTRY

June 15, 1977

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY

This report covers work done on Phases I and II of Project 3251 entitled "Water Recycle System Simulation." The objective of Phase I was concerned with the major improvements in computational efficiency of an existing dynamic simulation package (SIMPAK) program for its economic use for analyzing water reuse alternatives in a board mill. Both original and revised SIMPAK programs were applied to a simple pulping and cleaning system to illustrate the use of SIMPAK. A comparison of the computed results in the simulation runs, using both the original and revised SIMPAK programs, indicated that the revised SIMPAK program can cut computer time by a factor of nine (9) over the original SIMPAK program with essentially no change in the results.

The purpose of Phase II was to perform the initial phase of implementation of the revised SIMPAK program in a selected board mill. Efforts made in Phase II included the selection of a board mill in York, Pennsylvania, collection of the board mill data such as water and fiber flows in the white water system, translation of the board mill process flow diagram into a system laid out in the SIMPAK schematic form, and the preparation of the input data for the SIMPAK system for future application studies. The determination of best system closure alternative is yet to be undertaken.

A review of SIMPAK _vis a vis_ the needs of the industry was also undertaken. Based on this review and the similarity of many of the operations in the pulp and paper industry to those of the chemical industry, it was decided to terminate work on SIMPAK. The need for dynamic simulation of pulp and paper mills can best be

satisfied by obtaining a previously developed simulator from the chemical industry and adapting it to the pulp and paper industry. Routines developed for SIMPAK will be modified for this new simulation. The selection of which chemical process simulation is best suited for dynamic simulation studies at the Institute is in progress.

INTRODUCTION

The pulp and paper industry uses a large quantity of water of varying quality in almost every department of the mill from woodyards, through wet end, to finished products. The high cost or limited supply of process water can be an incentive for water recycling. Also, the stringent effluent guidelines by the Environmental Protection Agency will force the pulp and paper industry to make intensive reuse of water through effluent treatment processes, especially in-plant controls like internal process changes and recycling.

Despite the fact that the intensive reuse and recycle of process water has now become an important consideration in both pollution abatement and water utility, the question of when to implement water reuse and to what extent has not been yet articulated. Two dominant factors which control the extent to which recycling can be practiced are:

- Accumulation of dissolved solids
- Heat buildup

To enhance water recycling it is necessary to know the limiting concentration of dissolved material in water which can be utilized in a mill system, and to relate water of varying quality from different process steps to the points of usage. This can best be done by systems analysis.

On the basis of the systems analysis concept, a dynamic simulation package (SIMPAK) program was developed at The Institute of Paper Chemistry for a pulp and paper mill to determine how the system closure would affect the ultimate buildup in dissolved solids (DS) concentrations and how these concentrations would dynamically respond to the predictable variations and upsets. Because of its flexibility, SIMPAK can also provide the means for mills (1) to test the effect of operating policies, control strategies or any internal changes without actually modifying the real prototype system and (2) to assess the alternatives for prompt decision making between two or more courses of action.

The existing SIMPAK program is still in its development stage; it can be improved to extend its effective application for different systems through various modifications. For example, the initial development of SIMPAK was designed to meet the following two goals: (1) the computer program would utilize only a few basic unit blocks or modules which would be put together in any desired manner to approximately describe an actual or contemplated production process or area; (2) each basic unit block on the SIMPAK schematic diagram, identified by "block number," would be so arbitrarily assigned that the order in which block interconnections are specified is unimportant. Thus, the original SIMPAK system consists of a set of mainline and subroutine programs which are assembled in simple block diagram form to simulate the mill water flow system. In achieving the second goal, however, the mainline program incorporates an iterative scheme of calculations which is easy to program on a computer but does a lot more work than theoretically should be needed. (Such a measure involved 10 times repeated calculations at each integration interval in order to guarantee that the intermediate variables were at their proper values.) Hence, the computer time of SIMPAK in its simulation runs can be minimized simply through the refinement of the computational scheme and the revised SIMPAK program can be further verified in a selected board mill.

This research program (Project 3251) on water recycle system simulation is designed in four phases. Each of these phases represents a logical step in refinement of the existing SIMPAK program to accomplish the water reuse and recycle objectives as described in the next section.

OBJECTIVES

The main objectives of Project 3251 are:

1. To improve the existing SIMPAK program for its economical use for analyzing water reuse alternatives in a board mill.

2. To demonstrate how the improved SIMPAK program can be applied to this board mill for predicting the rate and extent of dissolved solids buildup during the extensive reuse of process water.

Project 3251 is conveniently divided into four phases. This report describes Phases I and II of the following four-phase project originally planned to be carried out at The Institute of Paper Chemistry in cooperation with St. Regis Paper Company:

1. Phase I — The refinement of the original SIMPAK program to increase the computational efficiency of the computer program.
2. Phase II — The preliminary work for implementation of the revised SIMPAK program in a selected board mill for water reuse analysis.
3. Phase III — The verification of the revised SIMPAK program against this board mill data.
4. Phase IV — The application studies of the revised SIMPAK program in this board mill to various system closure alternatives.

PHASE I — WORK PLAN

In the development of the original SIMPAK program, the initial attention was directed toward the construction of a simulation model to represent an entire pulp and paper mill in the least complicated manner possible. Other factors such as program structuring and computational efficiency were not taken into consideration.

The primary objective of this first phase was concerned with major improvement of the original SIMPAK program to achieve computational efficiency in the simulation runs. The secondary objective was to illustrate how to apply the original and revised SIMPAK program to a typical pulp mill. A typical set of the actual mill data was also used for initial testing of the revised SIMPAK program on its functional operation. Finally, an estimate of the computing speed in the simulation runs was also made for the improved SIMPAK program.

THE ORIGINAL SIMPAK PROGRAM

General Description

SIMPAK is an acronym for simulation package program which was developed on a "systems analysis" concept for describing the dynamic response of volume, flow, fiber, and chemical additive concentrations throughout any production process or system. This imitation of the real mill system is accomplished by constructing a series of simple building blocks or modules which correspond directly to the same production units or which can be hooked up to correspond to a more complex production process. Such basic modules of SIMPAK are the tanks, separators, mixers, distribution manifolds, and the connecting pipes as defined in Fig. 1. Time delays and process controllers are the basic components of SIMPAK which can be inserted wherever necessary but will not be used in the example that follows.

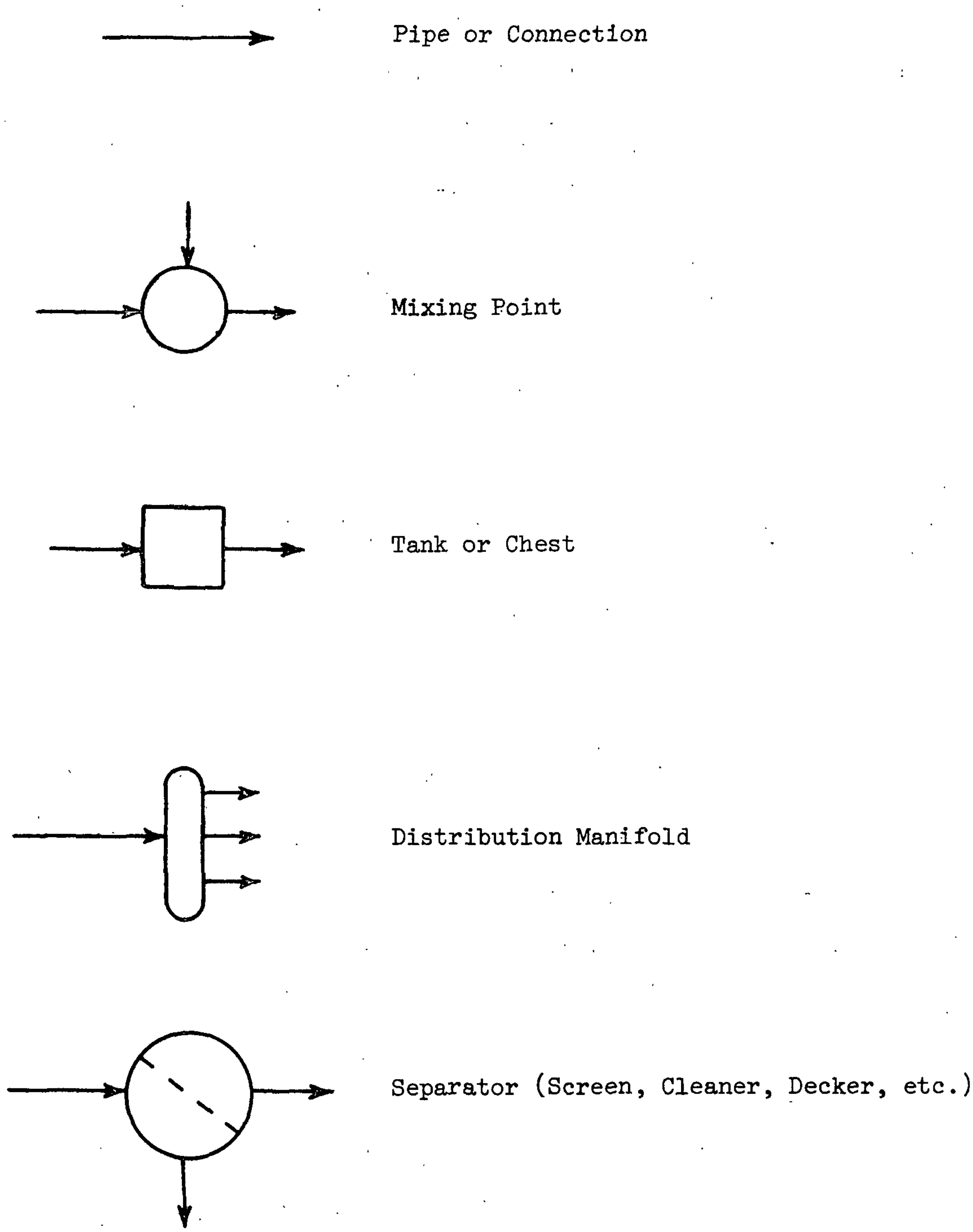


Figure 1. Basic Modules of the SIMPAK Program

The only module requiring more explanation is the separator. The separation of a mixture of water, fiber, and dissolved (or suspended) solids is a very common unit operation in the pulp and paper industry. Many different types of equipment are used at different process points to achieve this operation. Types of equipment which perform such separations include screens, knotters, centrifugal cleaners, deckers, drainers, selectifiers, paper machine wires, flat boxes, suction couches, wet presses, savealls, filters, clarifiers, etc. The way in which each of these separation units operates upon water, fiber, and dissolved (or suspended) solids is, of course, different from unit to unit. This difference is simply taken care of in the specification of the water, fiber, and additive characteristics for each of the separators in any system being studied.

For most systems, detailed information on the separation characteristics of the units is not readily available, but reasonable values may be derived from existing mill data and operating experience. Should any particular separator's characteristics turn out to be critical to the overall operation, then it would be worthwhile to do the experimental work needed to define more exactly the separation characteristics of the unit. The importance of a unit's characteristics can be determined by sensitivity analysis.

The SIMPAK Input

The use of SIMPAK can best be illustrated by an example. As a starting point one must have a complete piping and flow diagram, and actual data on the flow, fiber, and DS content. This process flow diagram will be translated unit by unit into a system laid out in the SIMPAK schematic form. After each process unit is represented on the SIMPAK diagram, with all the interconnecting pipes, each unit and each pipe is given a serial number which identifies that unit in the following data input and output lists. Figure 2 shows the SIMPAK schematic

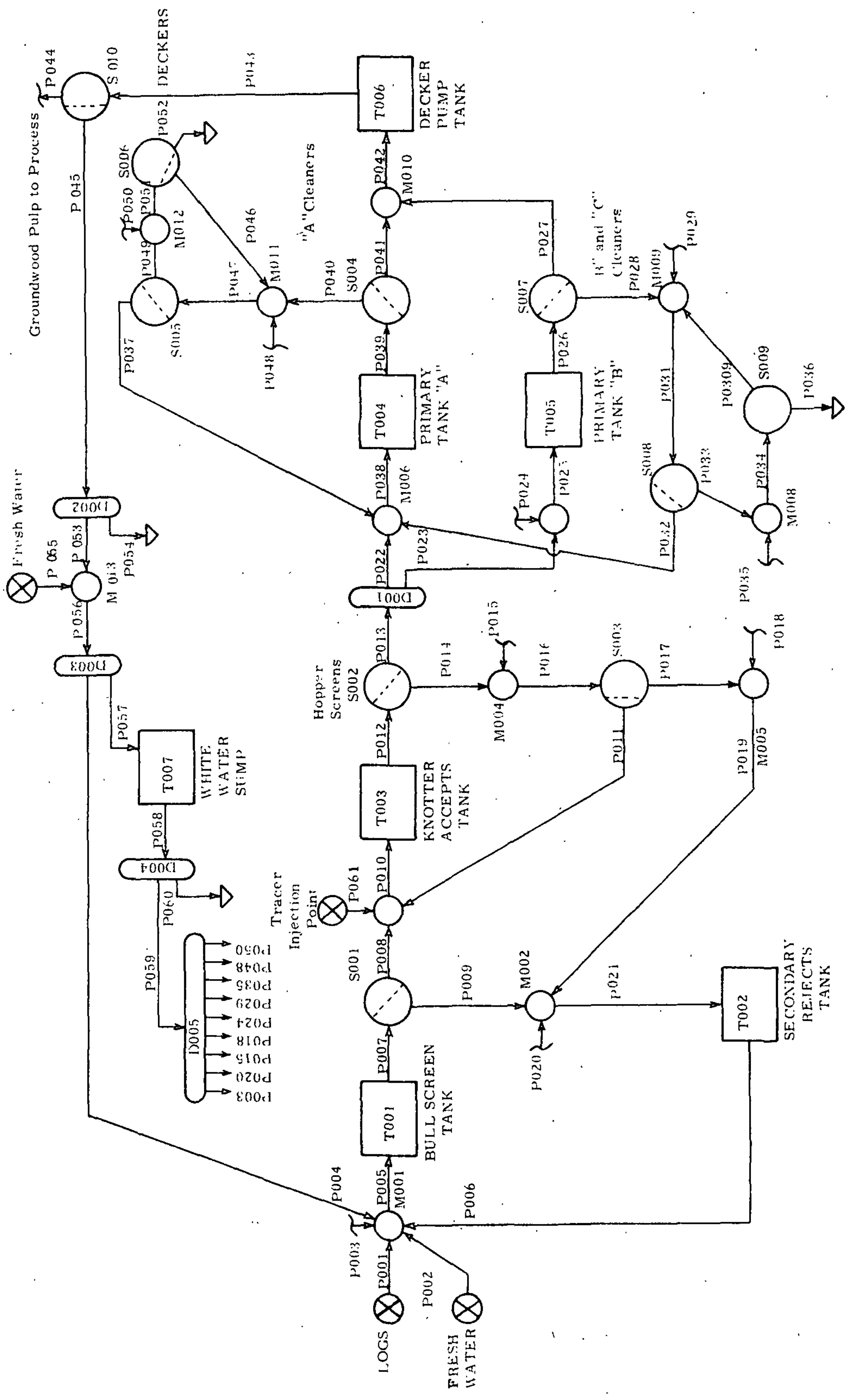


Figure 2. SIMPAK Schematic of Sartell Mill

which represents the complete pulp mill, cleaning, deckers, and white water reuse systems for the groundwood portion of the Sartell mill, Minnesota (St. Regis Paper Company) and also the serial numbers for the individual units.

Each process unit in the system has its unique set of parameters which must be determined. For instance, it is necessary to measure or estimate the volume of each tank, the separation of each screen or cleaner, and the volume of flow for each supply and sewer outlet. Thus, the procedure of the computer input is reduced to specifying the basic modules of SIMPAK within the system. Figure 3 shows a typical set of the computer input card deck corresponding to Fig. 2 for the complete pulp mill. The detailed description of the computer data input which is useful in interpreting changes to the input data deck and also for the use of the SIMPAK program by other personnel is given in Table I.

Table II shows the program listing of SIMPAK which consists of a mainline program and a series of modular subroutines. The flow diagram of the SIMPAK program is given in Fig. 4, and the details of this program are given in Appendix I.

SIMPAK Capability

SIMPAK can provide a calculated estimate of the dynamic response of the system to any operating changes after the connections and characteristics of the system have been specified. If changes in the system itself, such as repiping, addition or removal of a tank, or any other change, were contemplated, then it is a simple matter to revise the SIMPAK input data file to correspond to the changes and to repeat the computer experiment. This predictive capability is especially valuable where the contemplated changes are difficult and expensive to study directly in the mill without disturbing machine productivity or product quality, or when process equipment does not exist.

```
SIMPAK FOR ST. REGIS, SARTEL.  BROMINE INJECTION EXPERIMENT
01
999
999  THIS SIMULATION RUN WITHOUT CONTROLLERS ON EACH TANK
999
999
013 MIXERS
M001 1 005 05 001 002 003 004 006
M002 1 021 03 009 019 020
M003 1 010 03 008 011 061
M004 1 016 02 014 015
M005 1 019 02 017 018
M006 1 038 03 022 037 032
M007 1 025 02 023 024
M008 1 034 02 033 035
M009 1 031 03 028 029 030
M010 1 042 02 027 041
M011 1 047 03 040 046 048
M012 1 051 02 049 050
M013 1 056 02 053 055
010 SEPARATORS
S001 1 007 009 008 0.006 0.999 0.000     KNOTTERS
S002 1 012 014 013 0.106 0.878 0.000     HOOPER PRIMARY
S003 1 016 017 011 0.200 0.990 0.000     HOOPER SECONDARY
S004 1 039 040 041 0.240 0.883 0.000     PRIMARY A&B
S005 1 047 049 037 0.200 0.921 0.000     SECONDARY A&B
S006 1 051 052 046 0.420 0.630 0.000     TERTIARY A&B
S007 1 026 028 027 0.224 0.674 0.000     PRIMARY C
S008 1 031 033 032 0.200 0.922 0.000     SECONDARY C
S009 1 034 036 030 0.426 0.838 0.000     TERTIARY C
S010 1 043 044 045 0.910 0.924 0.000     DECKERS
005 DISTRIBUTORS
D001 1 013 02
  022   023
0.557 0.443 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D002 1 045 02
  053   054
0.950 0.050 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D003 1 056 02
  004   057
0.427 0.573 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D004 1 058 02
  059   060
0.892 0.108 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D005 1 059 09
  003   020   015   018   024   029   035   048   050
0.313 0.025 0.050 0.023 0.154 0.106 0.031 0.239 0.060 0.000
000 CONTROLLERS
  7 TANKS
T  1 2   5   7   8500.00    612.41      0.00
T  2 2  21   6    500.00     31.66      0.00
T  3 2  10  12   1500.00     99.85      0.00
T  4 2  38  39   2000.00    111.33      0.00
T  5 2  25  26   2000.00    110.89      0.00
T  6 2  42  43   6000.00    290.25      0.00
T  7 2  57  58   5220.00     22.15      0.00
 61 PIPES
P  1     298.00     0.0     0.0
P  2      18.00   148.80    0.0
P  3     500.60     2.12    0.0
P  4    1119.37     4.75    0.0
P  5    2015.97   160.74    0.0
P  6      80.00     5.07    0.0
P  7    2231.00   160.74    0.0
P  8    2231.00   159.78    0.0
P  9       0.00     0.96    0.00
P 10    2627.46   174.88    0.0
P 11     396.46    15.10    0.0
P 12    2627.00   174.88    0.0
P 13    2306.51   156.34    0.0
P 14     320.49    18.54    0.0
P 15      79.97     0.34    0.0
P 16     400.46    18.88    0.0
P 17       4.00     3.78    0.00
P 18      36.79     0.16    0.0
P 19      40.79     3.93    0.0
P 20      39.98     0.17    0.0
P 21      80.77     5.07    0.0
P 22    1284.72    87.08    0.0

P 23    1021.78    69.26    0.0
P 24     246.30     1.05    0.0
P 25    1268.08    70.30    0.0
P 26    1268.00    70.30    0.0
P 27    1108.23    54.56    0.0
P 28     159.77    15.75    0.0
P 29     169.53     0.72    0.0
P 30      67.48     2.27    0.0
P 31     396.78    18.74    0.0
P 32     365.83    14.99    0.0
P 33      30.95     3.75    0.0
P 34      80.53     3.96    0.0
P 35      49.58     0.21    0.0
P 36      13.05     1.69    0.0
P 37     729.83    30.47    0.0
P 38    2380.39   132.54    0.0
P 39    2381.00   132.54    0.0
P 40     278.58    31.81    0.0
P 41    2102.42   100.73    0.0
P 42    3210.66   155.29    0.0
P 43    3210.00   155.28    0.0
P 44     243.96   141.31    0.0
P 45    2966.04    13.98    0.0
P 46     131.61     4.65    0.0
P 47     792.43    38.09    0.0
P 48     382.25     1.62    0.0
P 49      67.60     7.62    0.0
P 50      95.96     0.41    0.0
P 51     158.56     8.02    0.0
P 52      26.96     3.37    0.0
P 53    2817.74    13.28    0.0
P 54     148.30     0.70    0.0
P 55     309.00     0.0     0.0
P 56    3126.74    13.28    0.0
P 57    1791.62     7.61    0.0
P 58    1793.00     7.61    0.0
P 59    1599.36     6.79    0.0
P 60     193.64     0.82    0.0
P 61       0.1      0.0     0.27
7    OUTPUTS FOR BROMINE TRACER EXPERIMENTS
2 001 3          BROMINE IN TANK 1
2 002 3          BROMINE IN TANK 2
2 003 3          BROMINE IN TANK 3
2 004 3          BROMINE IN TANK 4
2 005 3          BROMINE IN TANK 5
2 006 3          BROMINE IN TANK 6
2 007 3          BROMINE IN TANK 7
    0.1000000    DTIME
    5.00000      DPRT
  100.00000      DMAP
  200.00000      TFINAL
```

Figure 3. Data for SIMPAK for Sartell Mill

TABLE I

SIMPAK INPUT DATA VARIABLES AND FORMAT

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Units
1	1	1-80	Title of the company name and/or the objective of work	NTITLE	20A4	
2	Minimum=2	1-2	Total number of independent process groups	NGRP	I2	
		1-3	Any number of identifying cards, with 999 in first column in the given example		I3	
3	1	1-3	Total number of mixers in one process group	NMIXG	I3	
4	1 or more	0-1	M, mixers matrix	NM (KK,JJ)	1X	
		2-4	The specified number of mixer	"	I3	
		5-6	Types of mixer	"	I2	
		7-10	The outgoing pipe	"	I4	
		11-13	Total number of incoming pipes	"	I3	
		14-17 (18-48)	The individual incoming pipes, maximum=10	"	10I4	
5	1	1-3	Total number of separators in one process group	NSEPG	I3	
6	1 or more	0-1	S, separators matrix	NS (KK,JJ)	1X	
		2-4	The specified number of mixer	"	I3	
		5-6	Types of separator	"	I2	
		7-10	Incoming pipe number	"	I4	
		11-14	Rejects pipe number	"	I4	
		15-18	Accepts pipe number	"	I4	
		19-24	Fractional retention of solids in rejects pipe	RS (KK,JJ)	F6.3	
		25-30	Fractional pass-through of flow volume to accepts pipe	"	F6.3	
		31-36	Fractional sorbed additive on fiber	"	F6.3	
7	1	1-3	Total number of distributors	NDISTG	I3	
8	1 or more	0-1	D, distributors matrix	ND (KK,JJ)	1X	
		2-4	The specified distributor number	"	I3	
		5-6	Types of distributor	"	I2	
		7-10	Incoming pipe number	"	I4	
		11-13	Total number of outgoing pipes	"	I3	
9	1	1-5	Individual outgoing pipe	ND (KK,JJ)	I5	
		6-11 (12-59)	Individual outgoing pipe, maximum=9	"	9I6	
10	1	1-5	Distributors matrix to store the fractional	RD (KK,JJ)	F5,3	
		6-11 (12-59)	Distribution number to each outgoing pipe	"	9F6.3	
11	1	1-3	Total number of proportional controllers in one process group	NPCONG	I3	

TABLE I (Continued)

SIMPAK INPUT DATA VARIABLES AND FORMAT

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Units
12	1	0-1	C, controllers matrix (not given here)	NPC (KK,JJ)	1X	
	or more	2-4	The specified number of controller	"	I3	
	(missing in	5-6	Controller attached to tank or pipe	"	I2	
	the input	7-10	The specified tank or pipe number	"	I4	
	data list	11-12	Types of interest in flows (in tank or pipe)	"	I2	
	since there	13-15	Controller attached to tank or pipe	"	I2	
	is no con-	16-20	The specified tank or pipe number	"	I4	
	troller)	21-22	Types of interest in flows (in tank or pipe)	"	I2	
		1-10	Controllers matrix to store set point value	RPC (KK,JJ)	F10.2	
		11-19	and proportional gain	"	F11.2	
13	1	1-3	Total number of tanks in one process group	NTANKG	I3	
14	1	0-1	T, tanks matrix	NT (KK,JJ)	1X	
	or more	2-4	The specified number of tanks	"	I3	
		5-6	Types of tank	"	I2	
		7-10	Incoming pipe number	"	I4	
		11-14	Outgoing pipe number	"	I4	
		15-25	Tank volume	V (JT,JJ)	F10.2	gallons
		26-35	Mass of fiber	MF (JT,JJ)	F10.2	lb
		36-45	Mass of additive	MA (JT,JJ)	F10.2	lb
15	1	1-3	Total number of pipes in one process group	NPIPE	I3	
16	1	1			1X	
	or more	2-4	The specified number of pipe	K	I3	
		5-24	Flow rate	Q (JT,K)	F10.2	gal/min
		25-33	Mass flow rate of fiber	WF (JT,K)	F9.2	lb/min
		34-32	Mass flow rate of additive	WA (JT,K)	F9.2	lb/min
17	1	1	Total number of desired printed outputs	NOUT	I1	
18	1	1	The outputs vector to store type of process units (e.g., tanks, pipes, etc.)	NPRT 1 (JJ)	I1	
		2-5	The outputs vector to store the specified number of the process units which are of interest	NPRT 2 (JJ)	I4	
		6-7	The outputs vector to store the process variables such as volume, or flows	NPRT 3 (JJ)	I2	
19	1	1-10	Incremental time step	DTIME	F10.4	minutes
20	1	1-10	Desired print interval	DPRT	F10.4	
21	1	1-10	Desired map interval	DMAP	F10.4	
22	1	1-10	Total execution time	TFINAL	F10.4	minutes

TABLE II

THE ORIGINAL SIMPAK COMPUTER PROGRAM

I. Main Program

II. Subroutines

Subroutine	Explanation
1. MIX	Mixes a maximum of 10 incoming flows to give 1 outgoing flow
2. SEP	Splits an incoming flow into 2 outgoing flows
3. DIST	Distributes an incoming flow to a maximum of 10 outgoing flows
4. TANK	Calculates concentrations at each tank
5. PCON	Proportional controllers
6. HCON	Half power controllers
7. CONVAR	Selects the desired output variables
8. MAP	Displays flow at each pipe, fiber, additive and dissolved solids in tanks
9. DECODE	Specifies the desired information to be printed out
10. NAVEL	Calculates time constants
11. LINE	Prints the desired material stored in each tank in line array

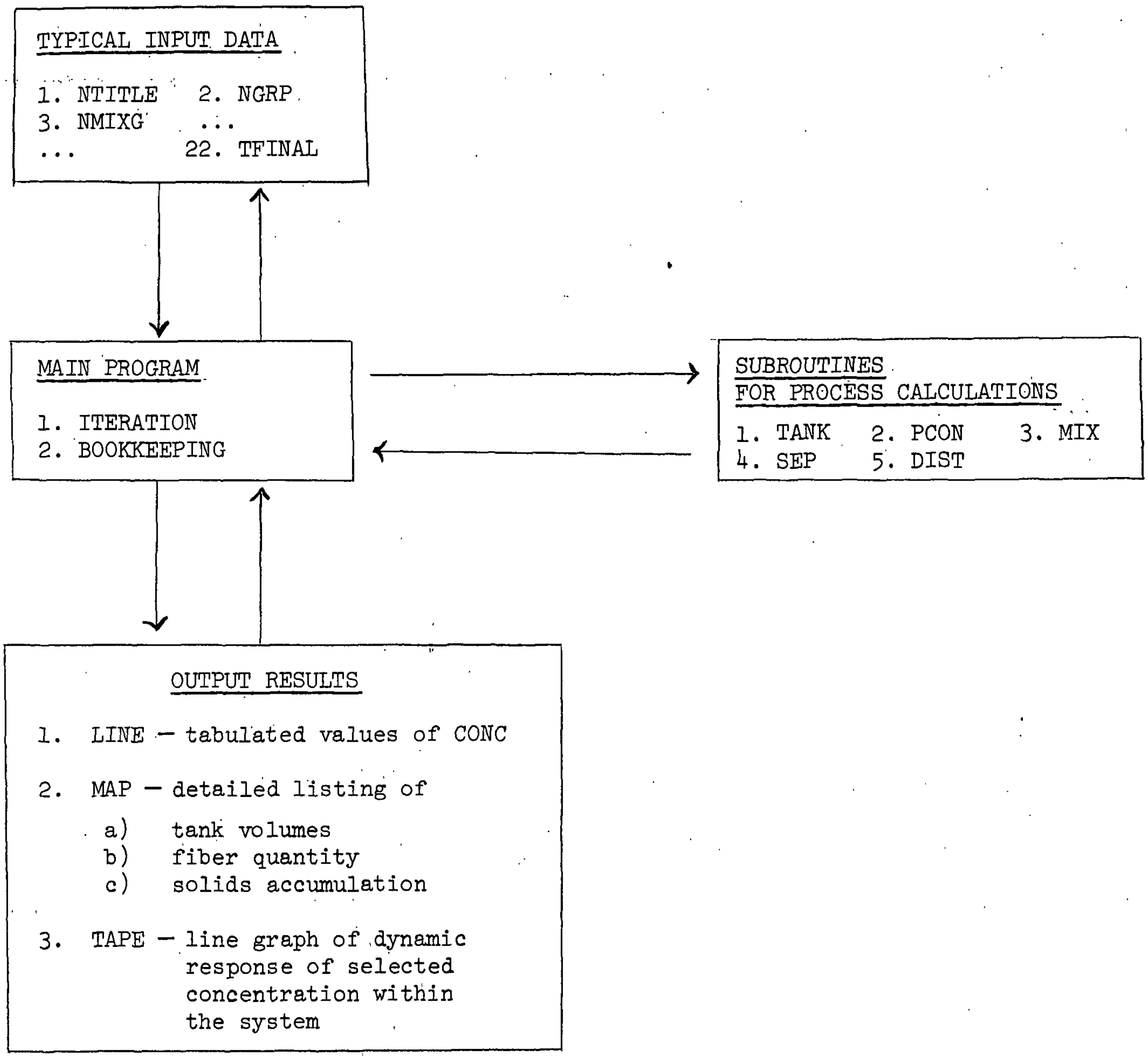


Figure 4. SIMPAK Computer System

<u>The SIMPAK Output</u>

The results from the simulation are available in three main forms. The first is a tabulated value of the concentration or consistency at a number of selected points as a function of time. Normally this list is used to obtain a close, continuous look at the changes in concentration which occur at critical points within the mill system.

The second form of results is a detailed printout of the tank volume, fiber quantity, and solids accumulation at every single point within the whole mill system. This printout is normally produced less frequently during the simulation experiment and is used mainly as a check on the proper logic and operation of the entire simulation.

The third form of the results is a computer-plotted line graph of the dynamic response of selected concentrations within the system. This graph, produced in an off-line operation, is derived from a magnetic tape copy of the output results which is made during the simulation experiment itself. The user must develop his own program to retrieve the desired information from this magnetic tape copy for various application purposes. A plotting subroutine is not part of SIMPAK.

THE REVISED SIMPAK PROGRAM

The SIMPAK program was revised specifically to improve computational efficiency by cutting the computer simulation run time in the use of SIMPAK. This new SIMPAK contains two additional subroutines in addition to slightly modifying the computation section in the mainline program of the original SIMPAK to perform a simple operation which avoids repetitive calculations. The two new subroutines are respectively called CONF and SORT. Table III lists the revised SIMPAK program, and the details of this new program are given in Appendix II.

TABLE III

THE REVISED SIMPAK COMPUTER PROGRAM

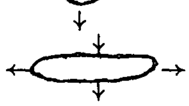
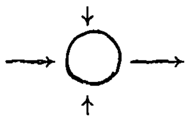
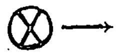
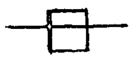
I.	Modified Main Program	
II.	Subroutines	Explanation
1.	MIX	Mixes a maximum of 10 incoming flows to give 1 outgoing flow
2.	SEP	Splits an incoming flow into 2 outgoing flows
3.	DIST	Distributes an incoming flow to a maximum of 10 outgoing flows
4.	TANK	Calculates concentrations at each tank
5.	PCON	Proportional controllers
6.	HCON	Half power controllers
7.	CONVAR	Selects the desired output variables
8.	MAP	Displays flow at each pipe, fiber, additive and dissolved solids in tanks
9.	DECODE	Specifies the desired information to be pointed out
10.	NAVEL	Calculates time constants
11.	LINE	Prints the desired material stored in each tank in line array
III.	New Subroutines	
1.	CONF	Specifies and prepares the SIMPAK configuration for order-sorting operation
2.	SORT	Determines the detailed sequence of the integrations and distributions among the basic modules of the SIMPAK system

The CONF Subprogram

The CONF subroutine provides a set of the SIMPAK configuration elements, plus a couple of special elements that the user can tailor to his particular needs. Table IV illustrates these elements, their language symbols, and descriptions of their functions.

TABLE IV

REPRESENTATIVE SIMPAK CONFIGURATION ELEMENTS

Elements	Language Symbols (Identifiers)	Descriptions	Identification Numbers (or Coding)
Tanks	T1, T2, ...		4
Separators	S1, S2, ...		2
Distributors	D1, D2, ...		3
Mixers	M1, M2, ...		1
Constants	C1, C2, ...		5
Holds	H1, H2, ...		6

The CONF subprogram is an abbreviation of the SIMPAK configuration which is used herein to describe the structure of the simulation block diagrams expressed in terms of language symbols as defined in Table IV. Thus, the user can use the same SIMPAK diagram derived from the process flow diagram, showing the interconnections among the elements required to implement his model. For example, Fig. 5 depicts the same Sartell pulp mill as shown in Fig. 2 except that two special language symbols were added. The inputs (Logs, Fresh Water, and Tracer Injection) are represented as the constant elements, C1, C2, C3, and C4. The hold elements,

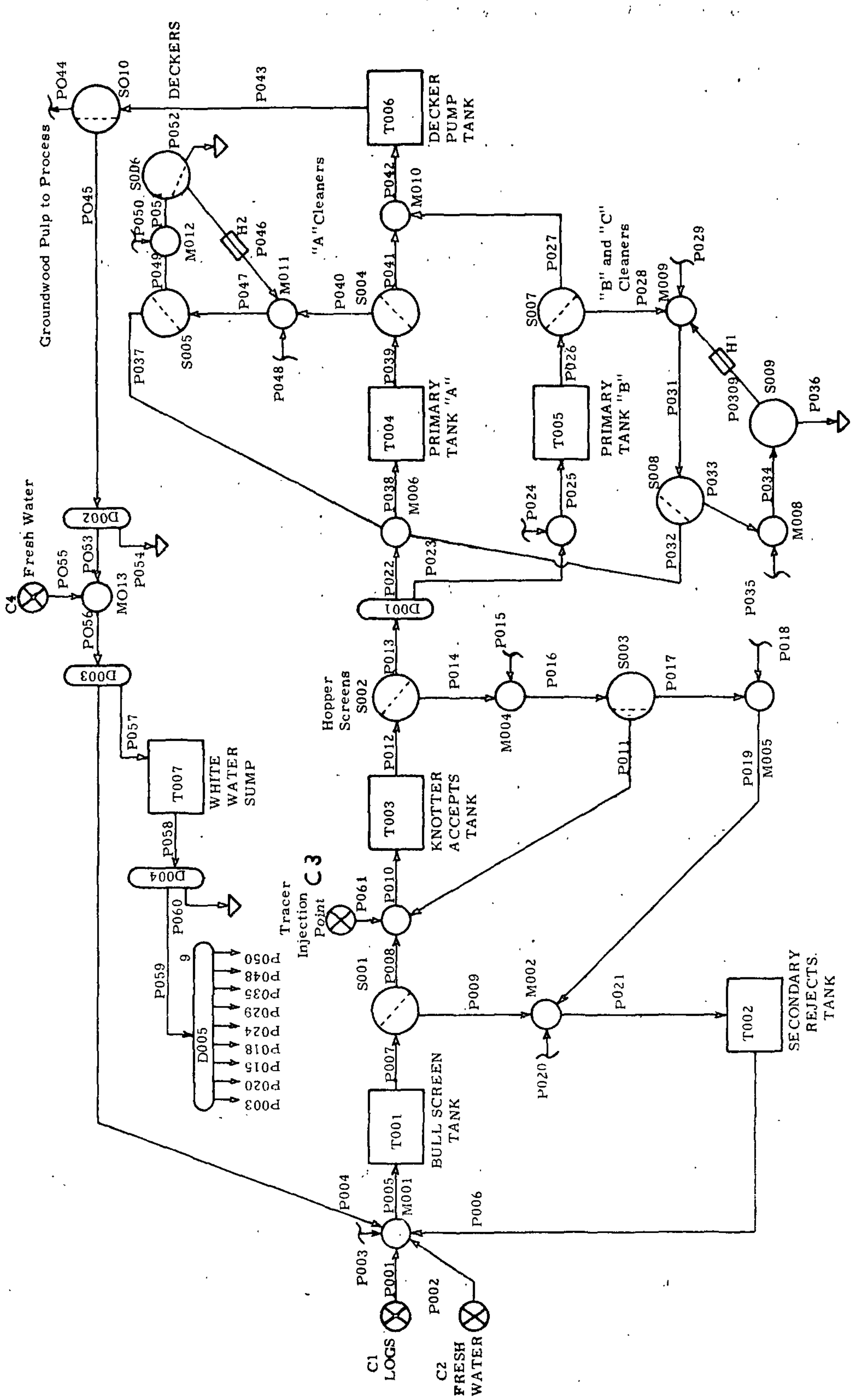


Figure 5. Schematic of Sartell Mill for Revised SIMPAK Program

H1 and H2, needed so break closed loops were inserted between Separator 009 and Mixer 009, and between Separator 006 and Mixer 011 in Fig. 5.

Translation of the SIMPAK configuration as shown in Fig. 5 into a computer program involves the use of configuration statements which define the interconnections among the basic modular blocks and specify the desired functional operation. These configuration statements can be prepared in any order. A fixed format simplifies the routine task of preparing the necessary input card deck either using punched cards or entering directly through the keyboard. Figure 6 contains detailed information about the language statements expressed in terms of numbers and shows one of the possible arrangements of configuration elements which can be made to correspond to the SIMPAK configuration of Fig. 5. The correct sequencing of the calculations is automatically performed by a sorting routine.

A few words concerning the array of numbers as shown in Fig. 6 may be in order. Each line of Fig. 6 represents an input data card which contains three parts of information. The first part contains a SIMPAK configuration element in serial number which can be arbitrarily specified. The second part includes five associated <u>incoming</u> elements in serial number. (Only mixer elements can have more than five incoming elements. Should any element contain more than five incoming elements, then either the element must be split in two or more new elements to reduce the number of incoming elements or the CONF subprogram can be slightly modified to provide enough room for the additional elements.) The last part contains the identification number (ID) indicating the type of modular elements and its sequence number. For example, tanks and separators have their corresponding ID Numbers 4 and 2.

Serial No.	Incoming Element Serial Numbers				ID	Sequence No.
1	23				4	1
2	24				4	2
3	25				4	3
4	28				4	4
5	29				4	5
6	32				4	6
7	20				4	7
8	1				2	1
9	3				2	2
10	26				2	3
11	4				2	4
12	33				2	5
13	34				2	6
14	5				2	7
15	31				2	8
16	30				2	9
17	6				2	10
18	9				3	1
19	17				3	2
20	35				3	3
21	7				3	4
22	21				3	5
23	2	20	22	38	39	1	1
24	22	8	27			1	2
25	8	10	40			1	3
26	22	9				1	4
27	10	22				1	5
28	18	15	12			1	6
29	18	22				1	7
30	22	15				1	8
31	36	22	14			1	9
32	11	14				1	10
33	37	11	22			1	11
34	22	12				1	12
35	19	41				1	13
36					5	1
37					5	2
38					5	3
39					5	4
40	16				6	1
41	13				6	2

Figure 6. SIMPAK Configuration Data for
Sartell Mill Simulation
(For Description See Text)

The SORT Subprogram

The SORT program defines the proper order for processing the modular blocks by means of a sorting algorithm. No modular block is allowed to be processed until updated values of its input variables are available. If the sorting algorithm indicates an improperly specified configuration, the program produces a diagnostic message. The most common cause for a sort error is the existence of an algebraic loop. This is a closed pathway in the simulation diagram that does not include a tank module. A special element called Hold (H) provided in the program must then be used to break the loop. Such a situation was encountered while testing the improved SIMPAK program in a simple cleaning and pulping system as shown in Fig. 5.

To mechanize the sorting process requires an advanced programming technique. However, the basic concept behind the sorting scheme is rather simple and can be briefly described in what follows.

At each integration interval, it is assumed that constants or inputs (the known inlets of fresh water and chemical additives or given outlets of sewer and other discharges) and the outputs of tank modules are available. A tank module is one in which the current output depends only on past values of the input and output. Using these constants and tank outputs, it is possible to process one or more other modules such as mixers, or separators, or distributors. These outputs then become available as inputs to additional modules. If the SIMPAK configuration is consistent, the logical sequencing of processing all the modular blocks can be determined in accordance with the sorting diagram, and all the blocks would carry sequential numbers to be processed in the modified mainline program.

In essence, the sorting procedure begins with repeating a line-by-line search from top to bottom of the SIMPAK configuration of Fig. 6 for the second part of information to check if all the associated incoming elements are known. (Initially only tanks and constants are assumed to be known.) Any element which has all its incoming elements available will be displaced to the top of the configuration map (Fig. 6) and assigned an ordinal number. This element now becomes available as an input to other unordered elements which must be repeatedly checked. Such a search process will continue until all the configuration elements are completely identified with proper ordinal numbers.

THE COMPUTED RESULTS

The revised SIMPAK program has been tested and run for a simple pulping system at Sartell, Minnesota as shown in Fig. 2. The purpose of doing this was twofold. First, it would provide the assurance that all portions of the program modified are reasonably debugged. Second, it would provide a base for estimating the computing speed of both the original and revised SIMPAK program.

To run the new version of SIMPAK requires a set of input data as given in Fig. 3. In addition to these data, an additional set of data, Fig. 6, which is prepared on the basis of Fig. 5, is needed to order the calculations.

The example problem tested was to study the dynamic behavior of the pulping system in response to the bromide ion injection at the pipeline P61 into the knotter accept tank T3, as shown in Fig. 2. The integration time step taken was 0.1 minute and the final simulation time was terminated at 200 minutes. The computer printouts were given at every 100th minute.

The partial listings of the computed results, using both the original and revised SIMPAK programs, are given in Tables V, VI, VII, and VIII. Although Tables V and VII show little difference in the dynamic change of bromine concentration level accumulated in each of seven (7) tanks, the revised SIMPAK program has cut the computer simulation time by a factor of nine over the existing SIMPAK program.

TABLE V

Bromine Buildup in the Tanks Using Original Program

Time, min	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7
5.0	0.12	0.00	0.19	0.17	0.19	0.39	0.14
10.0	0.43	0.02	0.24	0.25	0.27	0.67	0.39
15.0	0.71	0.04	0.30	0.32	0.34	0.90	0.59
20.0	0.97	0.05	0.34	0.39	0.40	1.10	0.77
25.0	1.20	0.07	0.38	0.44	0.46	1.28	0.92
30.0	1.40	0.09	0.42	0.50	0.51	1.44	1.06
35.0	1.57	0.10	0.45	0.54	0.56	1.59	1.18
40.0	1.73	0.11	0.48	0.58	0.60	1.71	1.28
45.0	1.87	0.12	0.50	0.62	0.63	1.82	1.38
50.0	1.99	0.13	0.53	0.65	0.66	1.92	1.46
55.0	2.10	0.14	0.55	0.68	0.69	2.01	1.53
60.0	2.20	0.15	0.56	0.70	0.72	2.09	1.60
65.0	2.29	0.16	0.58	0.72	0.74	2.16	1.66
70.0	2.36	0.16	0.59	0.74	0.76	2.22	1.71
75.0	2.43	0.17	0.60	0.76	0.77	2.27	1.75
80.0	2.49	0.17	0.62	0.77	0.79	2.32	1.79
85.0	2.54	0.18	0.62	0.79	0.80	2.36	1.83
90.0	2.59	0.18	0.63	0.80	0.82	2.40	1.86
95.0	2.63	0.18	0.64	0.81	0.83	2.43	1.89
100.0	2.67	0.19	0.65	0.82	0.84	2.46	1.91

TABLE VI

FINAL SIMULATION RESULTS USING ORIGINAL PROGRAM

SIMPAK FOR ST. REGIS, SARTEL. BROMINE INJECTION EXPERIMENT
FULL VARIABLE MAP AT TIME= 199.9999

THERE ARE 61 PIPES

FLOW RATE

298.00	18.00	500.60	1335.12	2231.71	80.00	2231.00	2228.77	2.23	2625.33
396.46	2627.00	2306.51	320.49	79.97	400.46	4.00	36.79	40.79	39.98
83.00	1284.72	1021.78	246.30	1268.08	1268.00	1108.23	159.77	169.53	67.48
396.78	365.83	30.95	80.53	49.58	13.05	729.83	2380.39	2381.00	278.58
2102.42	3210.66	3210.00	243.96	2966.04	131.61	792.43	382.25	62.60	95.96
158.56	26.96	2817.74	148.30	309.00	3126.74	1791.62	1793.00	1599.36	193.64
0.10									

MASS FLOW RATE OF FIBER

0.0	148.80	2.14	5.70	161.74	5.10	161.74	160.77	0.97	175.96
15.19	175.96	157.31	18.65	0.34	18.99	3.80	0.16	3.96	0.17
5.10	87.62	69.69	1.05	70.74	70.74	54.89	15.85	0.72	2.29
18.86	15.08	3.77	3.98	0.21	1.70	30.66	133.36	133.36	32.01
101.35	156.25	156.25	142.18	14.06	4.68	38.32	1.63	7.66	0.41
8.07	3.39	13.36	0.70	0.0	13.36	7.65	7.65	6.83	0.83
0.0									

MASS FLOW RATE OF ADDITIVE

0.0	0.0	0.20	0.54	0.77	0.03	0.77	0.77	0.00	1.22
0.18	1.22	1.07	0.15	0.03	0.18	0.00	0.01	0.02	0.02
0.03	0.59	0.47	0.10	0.57	0.57	0.50	0.07	0.07	0.03
0.17	0.15	0.01	0.03	0.02	0.01	0.30	1.05	1.05	0.12
0.93	1.43	1.43	0.11	1.32	0.05	0.33	0.15	0.03	0.04
0.06	0.01	1.25	0.07	0.0	1.25	0.72	0.72	0.64	0.08
0.27									

THERE ARE 7 TANKS

VOLUME

8500.00	500.00	1500.00	2000.00	2000.00	6000.00	5220.00

MASS OF FIBER STORED

616.21	31.85	100.47	112.02	111.58	292.05	22.28

MASS OF ADDITIVE STORED

2.93	0.21	0.69	0.88	0.90	2.67	2.09

TABLE VII

BROMINE BUILDUP IN THE TANKS USING REVISED PROGRAM

Time, min	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7
5.0	0.10	0.00	0.19	0.16	0.18	0.37	0.12
10.0	0.39	0.02	0.24	0.24	0.26	0.64	0.36
15.0	0.67	0.03	0.29	0.31	0.33	0.86	0.56
20.0	0.91	0.05	0.33	0.37	0.39	1.06	0.73
25.0	1.14	0.07	0.37	0.43	0.45	1.24	0.88
30.0	1.33	0.08	0.41	0.48	0.50	1.39	1.01
35.0	1.51	0.10	0.44	0.52	0.54	1.53	1.13
40.0	1.67	0.11	0.47	0.56	0.58	1.66	1.24
45.0	1.80	0.12	0.49	0.60	0.62	1.77	1.33
50.0	1.93	0.13	0.51	0.63	0.65	1.87	1.42
55.0	2.04	0.14	0.53	0.66	0.68	1.96	1.49
60.0	2.14	0.15	0.55	0.68	0.70	2.04	1.56
65.0	2.23	0.15	0.57	0.71	0.72	2.11	1.62
70.0	2.31	0.16	0.58	0.73	0.74	2.17	1.67
75.0	2.38	0.16	0.60	0.74	0.76	2.23	1.72
80.0	2.44	0.17	0.61	0.76	0.78	2.28	1.76
85.0	2.50	0.17	0.62	0.77	0.79	2.32	1.80
90.0	2.55	0.18	0.63	0.79	0.80	2.36	1.83
95.0	2.59	0.18	0.63	0.80	0.82	2.40	1.86
100.0	2.63	0.18	0.64	0.81	0.83	2.43	1.89

TABLE VIII

FINAL SIMULATION RESULTS USING REVISED PROGRAM

SIMPAK FOR ST. REGIS, SARTEL. BROMINE INJECTION EXPERIMENT
FULL VARIABLE MAP AT TIME= 199.9999

THERE ARE 61 PIPES

FLOW RATE

298.00	18.00	500.60	1335.12	2231.71	80.00	2231.00	2228.77	2.23	2625.33
396.46	2627.00	2306.51	320.49	79.97	400.46	4.00	36.79	40.79	39.98
83.00	1284.72	1021.78	246.30	1268.08	1268.00	1108.23	159.77	169.53	67.48
396.78	365.83	30.95	80.53	49.58	13.05	729.83	2380.39	2381.00	278.58
2102.42	3210.66	3210.00	243.96	2966.04	131.61	792.43	382.25	62.60	95.96
158.56	26.96	2817.74	148.30	309.00	3126.74	1791.62	1793.00	1599.36	193.64
0.10									

MASS FLOW RATE OF FIBER

0.0	148.80	2.14	5.70	161.74	5.10	161.74	160.77	0.97	175.96
15.19	175.96	157.31	18.65	0.34	18.99	3.80	0.16	3.96	0.17
5.10	87.62	69.69	1.05	70.74	70.74	54.89	15.85	0.72	2.29
18.86	15.08	3.77	3.98	0.21	1.70	30.66	133.36	133.36	32.01
101.35	156.25	156.25	142.18	14.06	4.68	38.32	1.63	7.66	0.41
8.07	3.39	13.36	0.70	0.0	13.36	7.65	7.65	6.83	0.83
0.0									

MASS FLOW RATE OF ADDITIVE

0.0	0.0	0.20	0.53	0.77	0.03	0.77	0.77	0.00	1.21
0.18	1.21	1.07	0.15	0.03	0.18	0.00	0.01	0.02	0.02
0.03	0.59	0.47	0.10	0.57	0.57	0.50	0.07	0.07	0.03
0.17	0.15	0.01	0.03	0.02	0.01	0.30	1.05	1.05	0.12
0.93	1.43	1.43	0.11	1.32	0.05	0.33	0.15	0.03	0.04
0.06	0.01	1.25	0.07	0.0	1.25	0.72	0.72	0.64	0.08
0.27									

THERE ARE 7 TANKS

VOLUME

8500.00	500.00	1500.00	2000.00	2000.00	6000.00	5220.00

MASS OF FIBER STORED

616.21	31.85	100.47	112.02	111.58	292.05	22.28

MASS OF ADDITIVE STORED

2.92	0.21	0.69	0.88	0.90	2.67	2.09

PHASE II — WORK PLAN

The second phase of this project involved the preliminary work necessary for a practical application of the improved SIMPAK program to a selected board mill for water reuse analysis. The work to have been completed in this phase was the following:

(1) Selection of a typical board mill

(2) Initial review of this board mill water system

(3) Collection of the mill material balance data

(4) Translation of the mill water flow diagram into the SIMPAK schematic diagram

(5) Preparation of a typical set of input data deck for SIMPAK computing purposes.

A medium-sized board mill with at least a moderate degree of water recycle was the criterion for the choice of a board mill for the application study of the revised SIMPAK program. The reasons for this are two. First, most board mills are the medium size. Second, a moderate degree of water reuse systems would generate enough information for various simulation studies.

Based on the above criterion, the St. Regis board mill at York, Pennsylvania was selected for this study. This board mill has a rather complex water flow system because of its high degree of system closure and is described below.

THE BOARD MILL

General Description of the Mill at York, PA

The mill at York is an integrated board mill which has three (3) hydrapulpers to pulp waste paper (carton, news and mixed), one cylinder board and two fourdrinier machines to produce 364 tons per day of paper and paperboard. At the time of our study approximately 275 gallons per minute of fresh water were entering the mill and a similar quantity was being passed to the various outlets either with product, or through evaporation in dryers, and sump and sewers for treatment and landfill. This represents approximately 1100 gallons of fresh water usage for each ton of paper produced.

The layout for the entire mill is shown in Fig. 7 using the SIMPAK symbols for the tanks, mixers, distributors, and separators (see Fig. 1). For better understanding of the mill system, the flow diagram (Fig. 7) has been divided into six detailed segments (D-1 through D-6) and separately shown in Fig. 7a through 7f. The details of the SIMPAK symbols can be obtained by referring to the input specifications in Appendix III, page 77.

The description of the entire board mill (Fig. 7) involves 62 major tanks, 72 mixing or blending points, 50 separators of various types, 31 distributors, and 332 pipeline connections. The high degree of water recycle and interdependence of the existing mill system are quite apparent in the detailed layout which represents the York mill's present operating arrangement. The details of the process flow diagram were identified and reviewed jointly by technical experts from the York mill, the St. Regis Technical Center, and The Institute of Paper Chemistry.

Operating Data for the Existing System

Based on extensive flow, consistency, and concentration measurements by the mill technical staff at York, a typical set of material balance data was synthesized and supplied by the St. Regis research staff for initial steady state flow rates and fiber consistencies throughout the entire board mill.

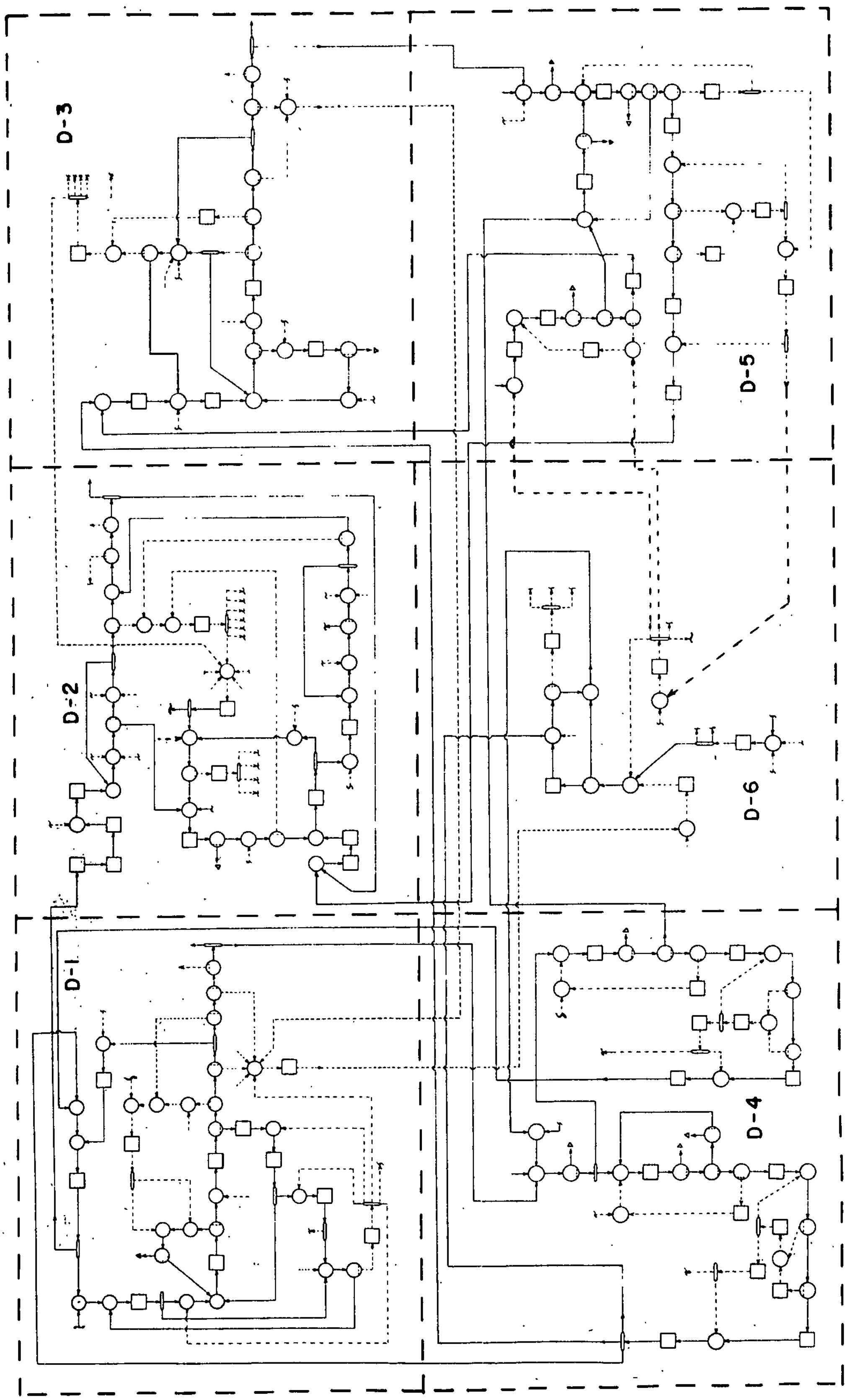


Figure 7. Schematic of St. Regis Board Mill at York, PA

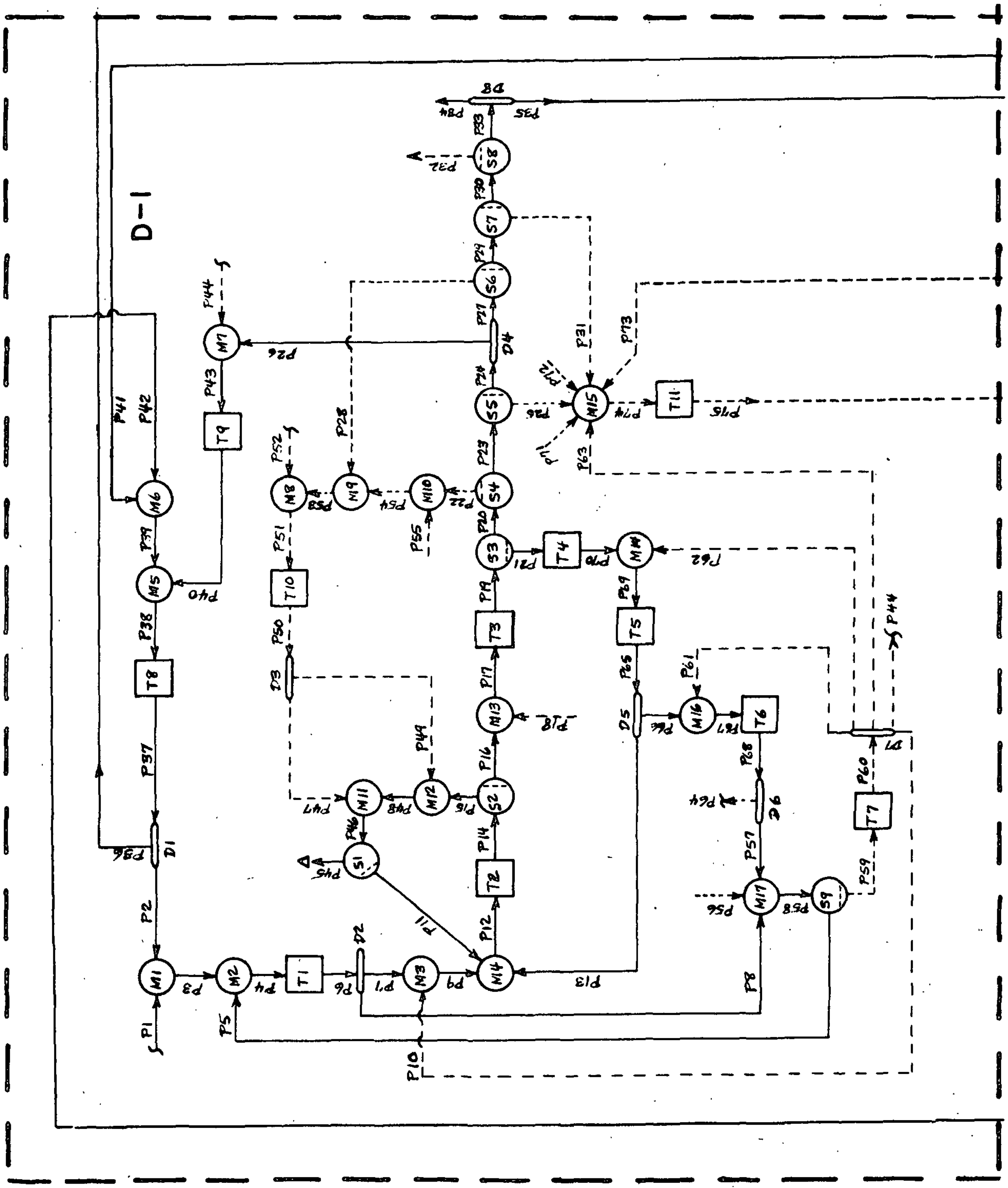


Figure 7a. Schematic of St. Regis Board Mill at York, PA

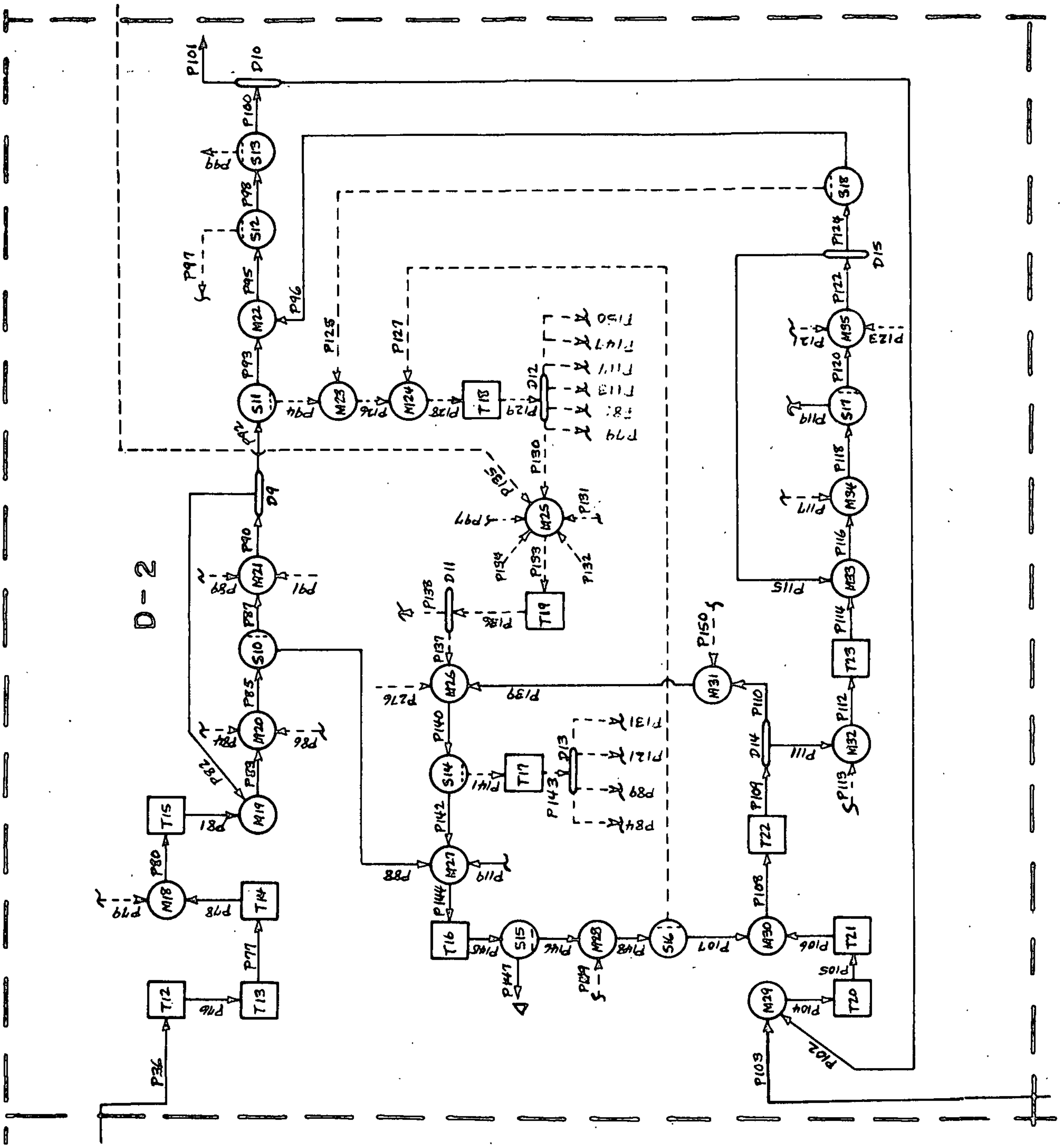


Figure 7b. Schematic of St. Regis Board Mill at York, PA

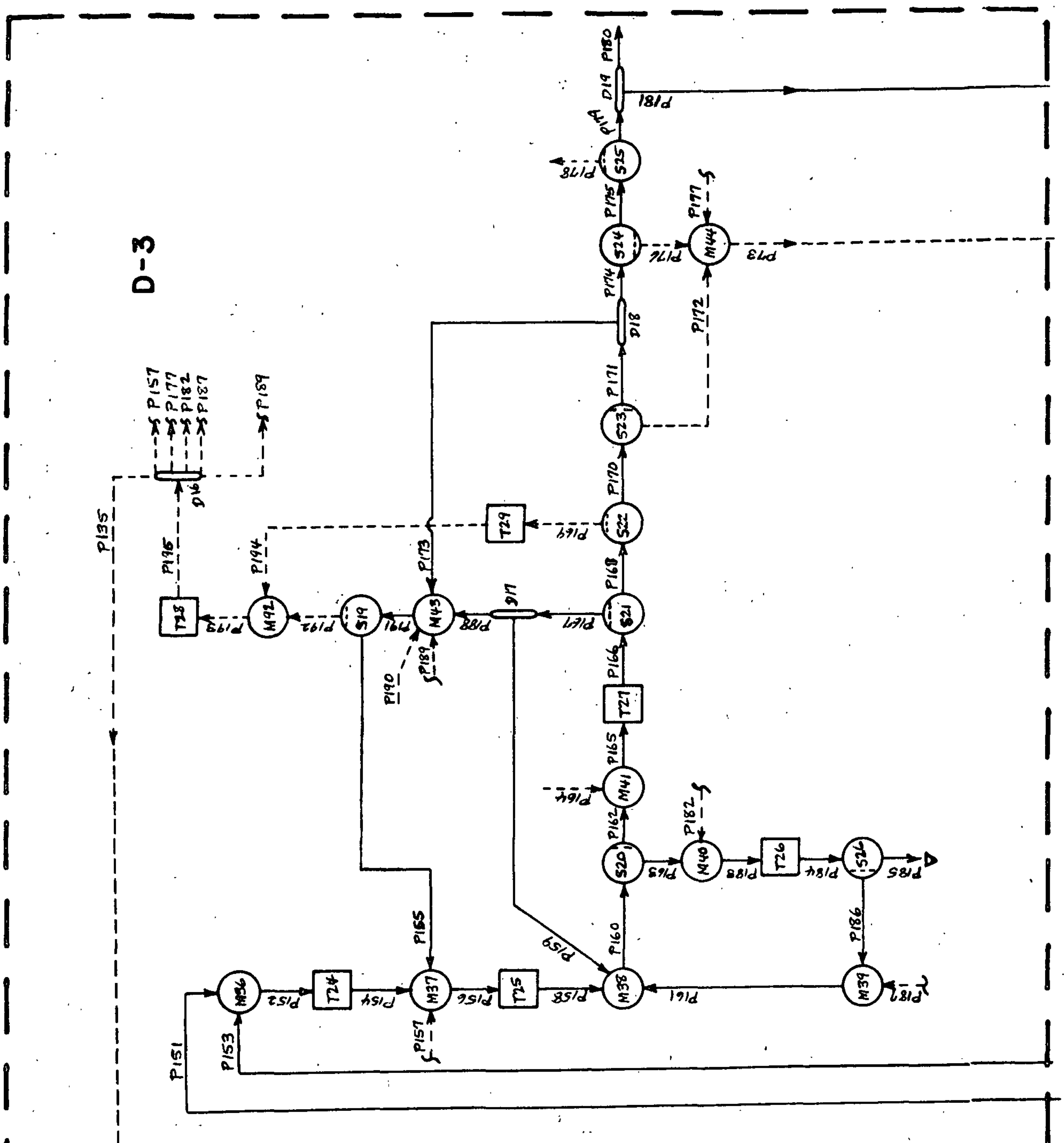


Figure 7c. Schematic of St. Regis Board Mill at York, PA

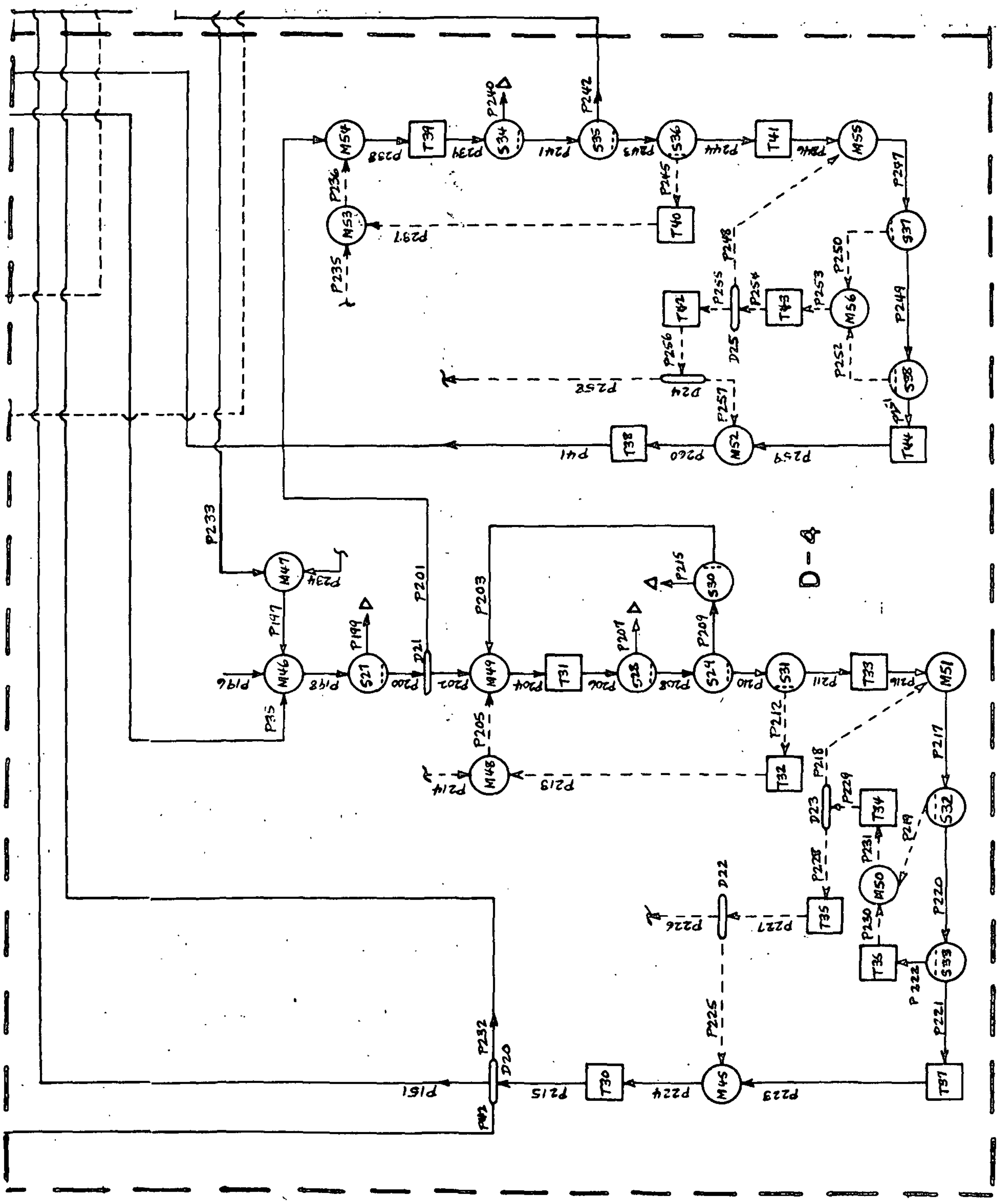


Figure 7d. Schematic of St. Regis Board Mill at York, PA

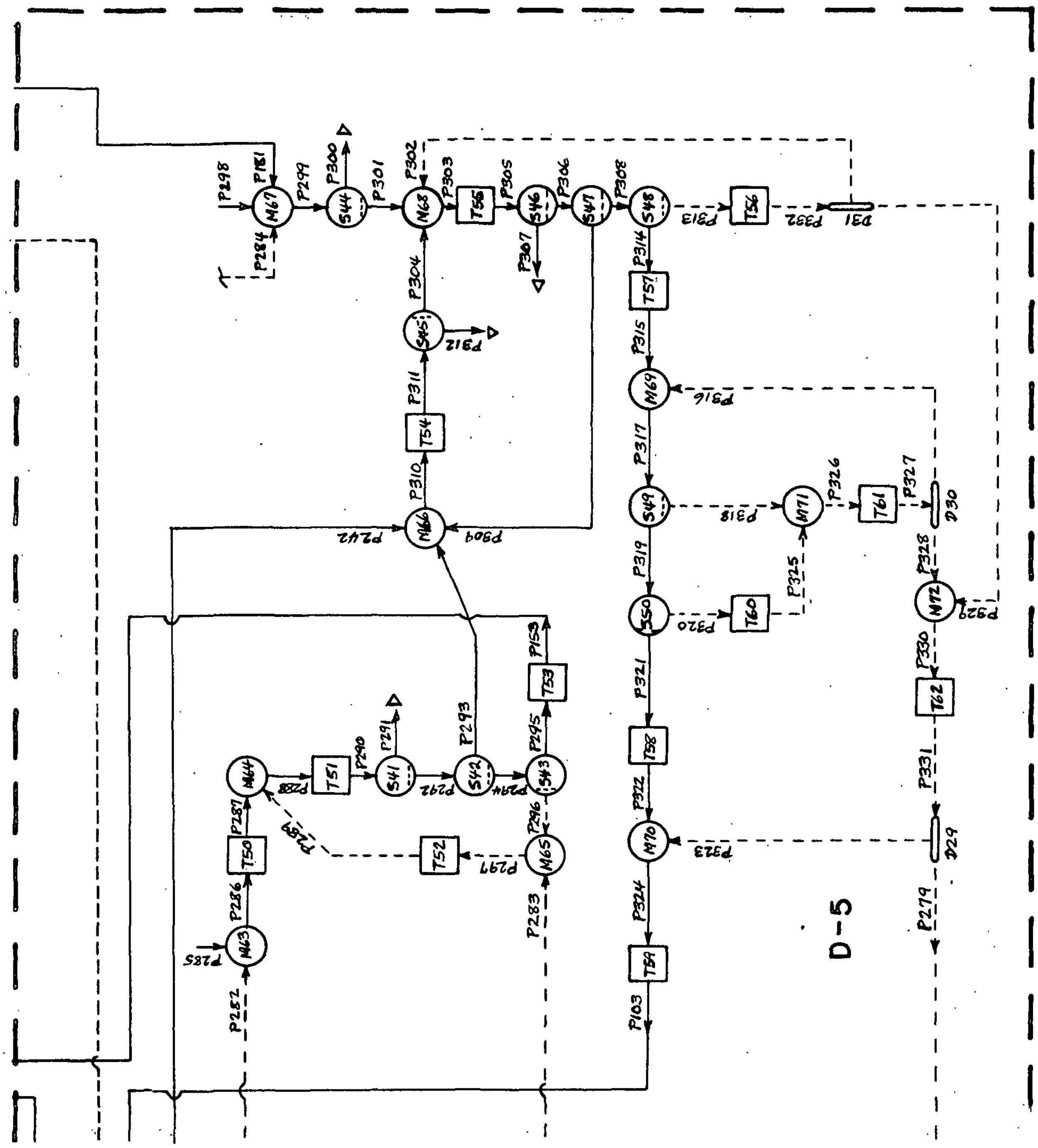


Figure 7e. Schematic of St. Regis Board Mill at York, PA

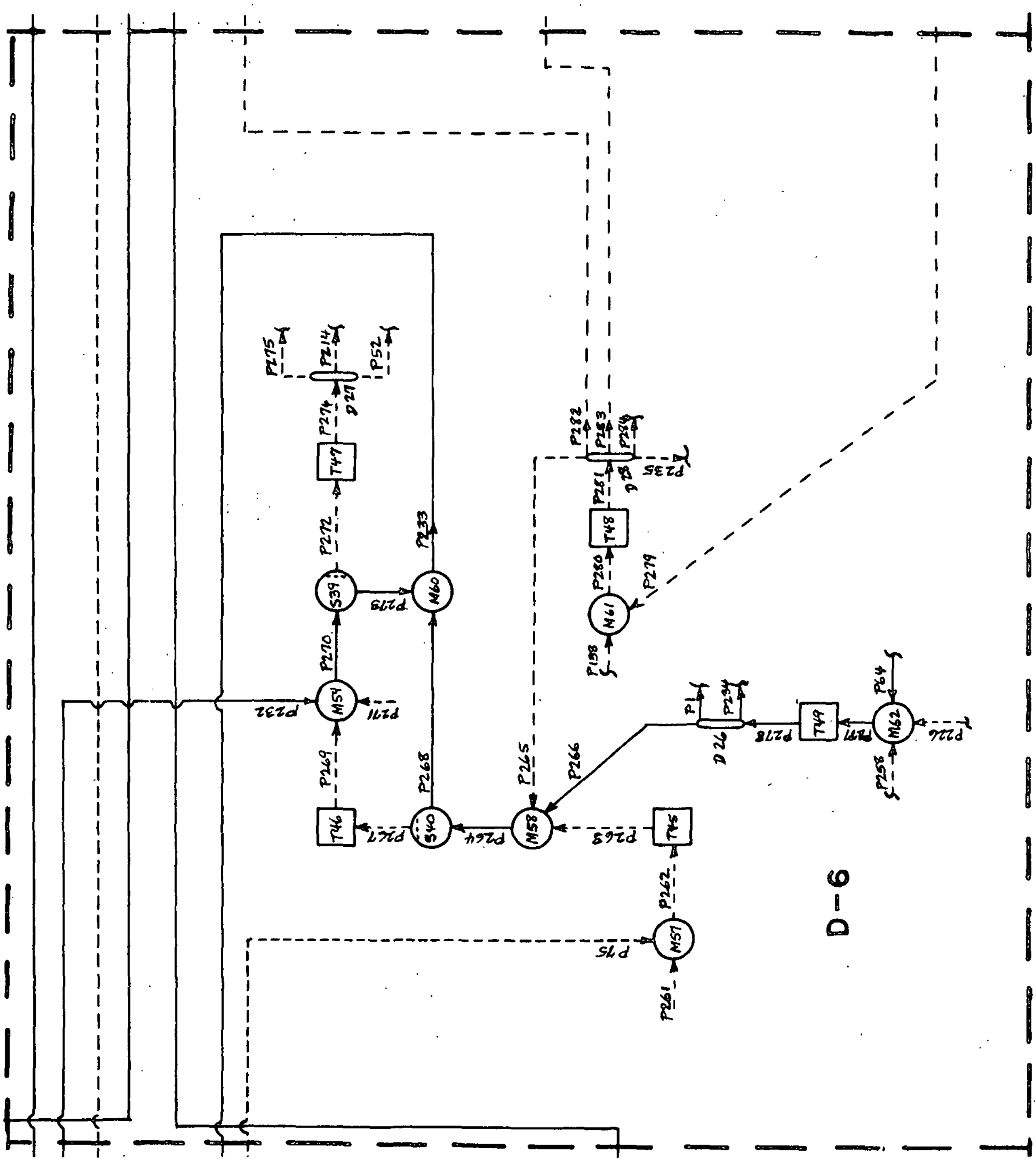


Figure 7f. Schematic of St. Regis Board Mill at York, PA

(Dissolved solids distribution within the system will be supplied at the time when simulation runs for various practical application studies are to be made.) These data were further checked and used by the Institute staff to determine the proper parameters for each of the individual components in the SIMPAK system. The parameters, as well as the water and fiber flow rates, are given in detail in the input data deck (Appendix III) for the initial steady state condition.

CONCLUSIONS

1. The original SIMPAK program has been revised to improve computational efficiency in the simulation runs.

2. The revised program has been tested and run on a small pulping system at Sartell, Minnesota in order to provide assurance that the improved model is workable and reasonably correct for the system under both the steady state and dynamic conditions.

3. A comparison of the computed results in the simulation runs, using both the original and revised SIMPAK programs indicated that the revised SIMPAK program can speed up the calculations by a factor of nine over the earlier SIMPAK program.

RECOMMENDATIONS

On the basis of the present work covering Phases I and II, the following avenues may be included for further studies to accomplish the ultimate goal of SIMPAK applications.

1. The prediction of the steady state and dynamic response of process water systems is a necessary part of decision making on the use or reuse of process water within a mill. Hence, it would be useful to make computer runs on the York board mill to demonstrate the capability and applicability of the revised SIMPAK program to such problems. The computed results would be compared with the actual data.

2. Once the revised SIMPAK program has been verified against actual board mill data, it can be readily used to study water quality parameters from various parts of the mill or at various points within the mill during the intensive recycling simulation. Evaluation of the predicted results based on varying water route systems will immediately lead to one of the best reroute alternatives to achieve the internal mill closure objectives.

3. An additional task would be the exercise of the revised model to determine the sensitivity and dynamics of additive retention in the system as a function of the degree to which the additive is adsorbed on the pulp fibers.

4. Further modifications to include fiber fines as a separate item or to include the several types of pulp separately are also possible.

FUTURE WORK

The work done in Phases I and II of this project and the work done in earlier projects have demonstrated the need for dynamic simulation of mill water systems. These simulation efforts have demonstrated that SIMPAK has the ability to predict the transient behavior of both fiber and dissolved solids in mill water systems. These studies have also indicated that it would be desirable to simulate the behavior of more components in the water system. Additionally, it would be desirable to simulate the behavior of many of the processes in a mill at a greater level of detail than presently incorporated into SIMPAK. For these reasons SIMPAK has been very carefully reviewed. This review was focused on the ability of SIMPAK to be easily expanded to incorporate more processes and components. Other dynamic simulators were also evaluated to compare simulation methodologies.

Based on this review, it has been concluded that the large effort necessary to expand SIMPAK to become a full mill simulation package could be avoided by obtaining the master control program from an already developed simulation package. The Institute would then concentrate its efforts on adopting existing SIMPAK subroutines and developing new subroutines for the new master control program. Several possible candidates for this new master control program are under consideration; all of them have undergone extensive development in the chemical industry.

The expanded simulation capability will be checked using the large data base that has been accumulated for use with SIMPAK. The increased simulation capability will then be used to study mechanisms to control the pulping and papermaking process to achieve a more uniform product, to develop optional water reuse strategies, and to study the influence of upsets on mill processes, including waste treatment facilities.

ACKNOWLEDGMENTS

We are very grateful to Messrs. Robert Roscoe and James Hulbert of St. Regis Paper Company for their active participation in the mill system definition, experimentation, and mill data collection and analysis necessary for this work. We also want to thank Dr. Delmar Raymond, West Nyack, New York and the people at York, St. Regis Paper Company, for their cooperation in this study.

THE INSTITUTE OF PAPER CHEMISTRY

James Y. Hung
Research Fellow

Peter E. Parker
Research Fellow

Approved by

Hardev S. Dugal
Director
Division of Industrial &
Environmental Systems

APPENDIX I

LISTING OF THE EXISTING SIMPAK PROGRAM

This appendix contains a listing of the original SIMPAK program (main-line and subroutines) used for the pulping system simulation.

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C       SIMPAK MAINLINE FOR SIMULATION OF MILL WATER SYSTEMS
C       ROBERT A. HOLM  THE INSTITUTE OF PAPER CHEMISTRY
C       COPYRIGHT 11 MAR 73
C       MODIFIED FOR TAPE OR DISK OUTPUT 12/28/73 J Y HUNG
        DIMENSION Q(2,400),WF(2,400),WA(2,400)
        DIMENSION V(2,75),MF(2,75),MA(2,75),NT(4,75)
        DIMENSION NM(14,100)
        DIMENSION NS(5,50),RS(3,50)
        DIMENSION ND(14,50),RD(10,50)
        DIMENSION NPC(7,50),RPC(2,50)
        DIMENSION NPRT1(7),NPRT2(7),NPRT3(7),NTITLE(20)
        INTEGER CRD,PRT,PCH,A(7,8)
        REAL MF,MA
        COMMON Q,WF,WA,V,MF,MA
C       THESE DIMENSION VARIABLES ARE INPUT TO THE CALL SUBROUTINES FOR
C       EACH MIXER, SEPARATOR, DISTRIBUTOR, CONTROLLER, AND TANK.  MAXIMUM
C       DIMENSION CAN BE CHANGED TO FIT THE SYSTEM TO BE SIMULATED OR
C       COMPUTER MEMORY AVAILABLE.    CAN PUT IN REPEATED CALLS, WITH
C       EXPLICIT STATEMENT OF EACH INPUT CONNECTION IN PLACE OF THESE
C       MATRICES.   Q,WF,WA,V,MF,MA  MUST REMAIN VECTORS, HOWEVER
C
        CALL WHEN
        CRD= 5
        PRT= 6
        PCH= 7
C
C       ZERO ALL DATA POSITIONS
C
        DO 15 KK=1,2
        DO 1 JJ=1,200
        Q(KK,JJ)=0.0
        WF(KK,JJ)=0.0
        WA(KK,JJ)=0.0
      1 CONTINUE
        DO 2 JJ=1,75
        V(KK,JJ)=0.0
        MF(KK,JJ)=0.0
        MA(KK,JJ)=0.0
      2 CONTINUE
     15 CONTINUE
        NMIX=0
        NSEP=0
        NDIST=0
        NPCON=0
        NTANK=0
        NPIPE=0
        JT= 1
        KT= 2
        ITER= 5
        ITER=2*ITER
C       ITER SETS THE NUMBER OF ITERATIONS IN THE RELAXATION PROCEDURE
C       AND MUST BE AN EVEN NUMBER EQUAL TO OR GREATER THAN THE LARGEST
C       NUMBER OF NON-TANK ELEMENTS IN ANY BRANCH OF THE SYSTEM
C
        READ(CRD,1001) NTITLE
   1001 FORMAT(20A4)
C
C       INPUT FULL SYSTEM CONFIGURATION AND PARAMETERS
C
C       THE SYSTEM MAY BE GROUPED INTO FUNCTIONAL AREAS OR BLOCKS
C       ANY NUMBER OF IDENTIFYING CARDS   (WITH 999 IN FIRST THREE COLUMNS
C       MAY BE INSERTED BEFORE EACH SET OF MIXERS TO IDENTIFY THAT BLOCK
C       EACH BLOCK MUST CONTAIN MIX,SEP,DIST,PCON,TANK, AND PIPE COUNTS
C       WITH SOME COUNTS ZERO IF THAT SORT OF UNIT IS NOT USED IN THAT
C       BLOCK
C
        READ(CRD,1004) NGRP
   1004 FORMAT(I2)
C
        DO 50 NG=1,NGRP
C
C       CHECK FOR 999 COMMENT CARDS PRECEDING MIXER IDENTIFICATION
     51 READ(CRD,1000) NMIXG
        IF(NMIXG-999) 52,51,51
   1000 FORMAT(I3)
     52 NSMIX=NMIX+1
        NMIX=NMIX+NMIXG
        IF(NMIXG)1021,1021,1020
   1020 DO 1006 JJ=NSMIX,NMIX
```

```
      READ(CRD,1007) (NM(KK,JJ),KK=1,14)
 1006 CONTINUE
 1007 FORMAT(1X,I3,I2,I4,I3,10I4)
C
 1021 READ(CRD,1000) NSEPG
      NSSEP=NSEP+1
      NSEP=NSEP+NSEPG
      IF(NSEPG)1023,1023,1022
 1022 DO 1005 JJ=NSSEP,NSEP
      READ(CRD,1008) (NS(KK,JJ),KK=1,5),(RS(KK,JJ),KK=1,3)
 1008 FORMAT(1X,I3,I2,3I4,3F6.3)
 1005 CONTINUE
C
 1023 READ(CRD,1000) NDISTG
      NSDIS=NDIST+1
      NDIST=NDIST+NDISTG
      IF(NDISTG)1025,1025,1024
 1024 DO 1011 JJ=NSDIS,NDIST
      READ(CRD,1012) (ND(KK,JJ),KK=1,4)
 1012 FORMAT(1X,I3,I2,I4,I3)
      READ(CRD,1016) (ND(KK,JJ),KK=5,14)
 1016 FORMAT(I5,9I6)
      READ(CRD,1017) (RD(KK,JJ),KK=1,10)
 1017 FORMAT(F5.3,9F6.3)
 1011 CONTINUE
C
 1025 READ(CRD,1000) NPCONG
      NSCON=NPCON+1
      NPCON=NPCON+NPCONG
      IF(NPCONG)1027,1027,1026
 1026 DO 1018 JJ=NSCON,NPCON
      READ(CRD,1019) (NPC(KK,JJ),KK=1,7),(RPC(KK,JJ),KK=1,2)
 1019 FORMAT(1X,I3,2(I2,I4,I2),F10.2,F9.2)
 1018 CONTINUE
C
 1027 READ(CRD,1000) NTANKG
      NSTAN=NTANK+1
      NTANK=NTANK+NTANKG
      IF(NTANKG)1029,1029,1028
 1028 DO 1030 JJ=NSTAN,NTANK
      READ(CRD,1031) (NT(KK,JJ),KK=1,4),V(JT,JJ),MF(JT,JJ),MA(JT,JJ)
 1031 FORMAT(1X,I3,I2,2I4,3F10.2)
 1030 CONTINUE
C
 1029 READ(CRD,1000) NPIPEG
      NSPIP=NPIPE+1
      NPIPE=NPIPE+NPIPEG
      IF(NPIPEG)1033,1033,1032
 1033 WRITE(PRT,1034)
 1034 FORMAT(1H ,'WHY ARE THERE NO PIPES...')
      GO TO 1035
 1032 DO 1035 JJ=NSPIP,NPIPE
      READ(CRD,1036) K,Q(JT,K),WF(JT,K),WA(JT,K)
 1036 FORMAT(1X,I3,F10.2,2F9.2)
 1035 CONTINUE
C
   50 CONTINUE
C     UNTIL ALL GROUPS HAVE BEEN READ
C
C     END OF SYSTEM INPUT
C
C     SET NUMBER OF DESIRED PRINTED OUTPUTS AND THEIR IDENTITY
      READ(CRD,1013) NOUT
 1013 FORMAT(I1)
      DO 1014 JJ=1,NOUT
      READ(CRD,1015) NPRT1(JJ),NPRT2(JJ),NPRT3(JJ),(A(JJ,K),K=1,8)
 1015 FORMAT(I1,I4,I2,8A4)
 1014 CONTINUE
C
C     SET TIME STEP, PRINT INTERVAL, MAP INTERVAL, AND END POINT
      READ(CRD,1010) DTIME
      READ(CRD,1010) DPRT
      READ(CRD,1010) DMAP
      READ(CRD,1010) TFINAL
 1010 FORMAT(F10.4)
      NPRT=(DPRT/DTIME)+0.5
      NMAP=(DMAP/DPRT)+0.5
      NSTOP=(TFINAL/DMAP)+0.5
      TIME=0.0
```

```
      WRITE(PRT,1003) NTITLE
 1003 FORMAT(1H ,20A4)
      WRITE(PRT,3000) DTIME,DPRT,DMAP,TFINAL
 3000 FORMAT(1H ,2X,'DTIME =',F10.4,/,3X,'DPRT  =',F10.4,/,
     1           3X,'DMAP  =',F10.4,/,3X,'TFINAL=',F10.4)
      WRITE(PRT,1002) (NPRT1(J),NPRT2(J),NPRT3(J),J=1,NOUT)
 1002 FORMAT(1H ,'OUTPUT CODES ARE',7(I3,I4,I2))
C     WRITE TO TAPE N ITEMS AND OUTPUT CODES
      NTAPE=NSTOP*NMAP
      WRITE(1,9001) NOUT,NTAPE
 9001 FORMAT(8A4)
      DO 170 J=1,NOUT
 170  WRITE(1,9002)   NPRT1(J),NPRT2(J),NPRT3(J),(A(J,K),K=1,8)
 9002 FORMAT(3A4/8A4)
C
C     SET ALL VARIABLES EQUAL FOR PRESENT TIME AND TIME + DTIME.
C     THIS WILL COVER ALL CONSTANT INPUTS FOR CONTINUED CALCULATIONS
C     AND ANY THAT ARE NOT CONSTANT WILL SIMPLY BE OVERLAID
      DO 18 JJ=1,200
      Q(KT,JJ)=Q(JT,JJ)
      WF(KT,JJ)=WF(JT,JJ)
      WA(KT,JJ)=WA(JT,JJ)
   18 CONTINUE
      DO 19 JJ=1,75
      V(KT,JJ)=V(JT,JJ)
      MF(KT,JJ)=MF(JT,JJ)
      MA(KT,JJ)=MA(JT,JJ)
   19 CONTINUE
C
C           START  THE SYSTEM AT PROPER EQUILIBRIUM FOR ARBITRARY
C     INITIAL STATE VECTOR OF TANK VOLUMES
      JT= 1
      KT= 2
      INIT=1
      CALL MAP(NPIPE,NTANK,PRT,-1.0,NTITLE,JT)
      GO TO 35
   36 CONTINUE
      JT= 1
      KT= 2
      INIT=2
      CALL MAP(NPIPE,NTANK,PRT,0.0,NTITLE,JT)
C     CALL NAVEL(NT,NTANK,PRT)    CLOSED FOR PROJ 3299  12/22/75
C
C     MAIN RETURN POINT
C
      DO 12 LLL=1,NSTOP
      DO 7 KKK=1,NMAP
      DO 3 JJJ=1,NPRT
C
      IF(NTANK) 33,33,32
   32 DO 34 J=1,NTANK
      CALL TANK(J,NT(2,J),DTIME,NT(3,J),NT(4,J),JT,KT)
   34 CONTINUE
C     CALL MAP(NPIPE,NTANK,PRT,34.0,NTITLE,JT)
   35 CONTINUE
C
   33 DO 27 MMM=1,ITER
C     THIS IS AN APPROXIMATE REPLACEMENT FOR DETAILED SEQUENCING OF
C     SYSTEM NETWORK ELEMENTS BY SUCCESSIVE RELAXATION OF ALL NON-
C     STORAGE ELEMENTS IN THE SYSTEM
C
      IF(NPCON) 30,30,29
   29 DO 31 J=1,NPCON
      CALL PCON(J,NPC(2,J),RPC(1,J),JT,KT,NTANK,NT)
   31 CONTINUE
C     CALL MAP(NPIPE,NTANK,PRT,31.0,NTITLE,KT)
   30 IF(NMIX) 21,21,20
   20 DO 22 J=1,NMIX
      CALL MIX(J,NM(2,J),JT,KT)
   22 CONTINUE
C     CALL MAP(NPIPE,NTANK,PRT,22.0,NTITLE,KT)
C
   21 IF(NSEP) 24,24,23
   23 DO 25 J=1,NSEP
      CALL SEP(J,NS(2,J),RS(1,J),JT,KT)
   25 CONTINUE
C     CALL MAP(NPIPE,NTANK,PRT,25.0,NTITLE,KT)
C
   24 IF(NDIST) 38,38,26
```

```
   26 DO 28 J=1,NDIST
      CALL DIST(J,ND(2,J),RD(1,J),JT,KT)
   28 CONTINUE
C     CALL MAP(NPIPE,NTANK,PRT,28.0,NTITLE,KT)
   38 IF(JT-1) 16,16,17
   16 JT= 2
      KT= 1
      GO TO 27
   17 JT= 1
      KT= 2
C
   27 CONTINUE
      IF(INIT-1) 36,36,37
   37 CONTINUE
C
      RNDT=JJJ+NPRT*(KKK-1)+NMAP*NPRT*(LLL-1)
      TIME=DTIME*RNDT
    3 CONTINUE
      CALL LINE(TIME,NOUT,NPRT1,NPRT2,NPRT3,PRT,JT)
    7 CONTINUE
      CALL MAP(NPIPE,NTANK,PRT,TIME,NTITLE,JT)
   12 CONTINUE
C     CALL NAVEL(NT,NTANK,PRT)       CLOSED TEMPORARILY FOR SCOTT PROJ
      WRITE(PCH,998) NTANK
  998 FORMAT(I3,' TANKS')
  999 FORMAT(I3,' PIPES')
      DO 1037 J=1,NTANK
      WRITE(PCH,1038) (NT(K,J),K=1,4),V(1,J),MF(1,J),MA(1,J)
 1037 CONTINUE
 1038 FORMAT('T',I3,I2,2I4,3F10.2)
      WRITE(PCH,999) NPIPE
      DO 1039 J=1,NPIPE
      WRITE(PCH,1040) J,Q(1,J),WF(1,J),WA(1,J)
 1039 CONTINUE
 1040 FORMAT('P',I3,F10.2,2F9.2)
C     END THE TAPE FILE
      END FILE 1
      CALL EXIT
      END
```

```
      SUBROUTINE MIX(J,IN,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION IN(13)
      INTEGER OUT,N,IN,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY,COPYRIGHT11MAR73
C     TYPE SPECIFIES WHICH THINGS MAY CHANGE FOR THIS SIMULATION
C  (1)EVERYTHING   (2)FIBER AND ADDITIVE, BUT NOT FLOW   (3)ADDITIVE ONLY
C     SKIPPING CALCULATIONS SHOULD SPEED UP THE CALCULATION AND IMPROVE
C     ITS ACCURACY.  FOR INITIAL  TESTS AT CONSTANT FLOW, TYPE=2
C
      TYPE=IN(1)
      OUT=IN(2)
      N=IN(3)
      K=N+3
      GO TO (1,2,3),TYPE
C     ADD UP TOTAL FLOW
    1 QD=0.0
      DO 4 JJ=4,K
      KK=IN(JJ)
      QD=QD+Q(JT,KK)
    4 CONTINUE
      Q(KT,OUT)=QD
C
    2 WFD=0.0
C     ADD UP TOTAL FIBER RATE
      DO 5 JJ=4,K
      KK=IN(JJ)
      WFD=WFD+WF(JT,KK)
    5 CONTINUE
      WF(KT,OUT)=WFD
C
C     ADD UP TOTAL ADDITIVE RATE
    3 WAD=0.0
      DO 6 JJ=4,K
      KK=IN(JJ)
      WAD=WAD+WA(JT,KK)
    6 CONTINUE
      WA(KT,OUT)=WAD
      RETURN
      END
```

```
      SUBROUTINE SEP(J,N,R,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION N(4),R(3)
      INTEGER IN,REJ,ACC,TYPE
      REAL MF,MA
      REAL KF
      COMMON Q,WF,WA,V,MF,MA
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     NOTE THAT RF IS FRACTIONAL RETENTION OF SOLIDS IN REJ(ECTS) LINE
C     AND AQ IS FRACTIONAL PASS-THRU OF FLOW VOLUME TO ACC(EPTS) LINE
C
C     TYPE SHOWS WHETHER FIBER RATES (TYPE 3) OR VOLUMETRIC FLOWS (TYPE
C     2) ARE CONSTANT, OR ALL ARE VARIABLE (TYPE1)
C     FOR INITIAL TESTS, TYPE=2
      TYPE=N(1)
      IN=N(2)
      REJ=N(3)
      ACC=N(4)
      RF=R(1)
      AQ=R(2)
      KF=R(3)
C
      GO TO (1,2,3),TYPE
C     CALCULATE VOLUMETRIC FLOW SEPARATION
    1 Q(KT,REJ)=Q(JT,IN)*(1.0-AQ)
      Q(KT,ACC)=Q(JT,IN)-Q(KT,REJ)
C
C     CALCULATE FIBER MASS FLOW SEPARATION
    2 WF(KT,REJ)=WF(JT,IN)*RF
      WF(KT,ACC)=WF(JT,IN)-WF(KT,REJ)
C
C     CALCULATE BALANCE OF ADDITIVE SORBED ON FIBER
C     IF PERFECTLY SOLUBLE AND NOT ABSORBED, KF=0.0
    3 DENOM=Q(JT,IN)+KF*WF(JT,IN)
      IF(DENOM) 8,8,7
    7 CAW=WA(JT,IN)/DENOM
      WAF=KF*CAW
      GO TO 9
    8 CAW=0.0
      WAF=0.0
C     CALCULATE TOTAL DISSOLVED AND SORBED ADDITIVE LEAVING AT EACH PIPE
    9 WA(KT,REJ)=Q(KT,REJ)*CAW+WF(KT,REJ)*WAF
      WA(KT,ACC)=Q(KT,ACC)*CAW+WF(KT,ACC)*WAF
      RETURN
      END
```

```
      SUBROUTINE DIST(J,NQ,QF,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NQ(13),QF(10)
      INTEGER OUT,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     TYPE SIGNIFIES VARIABLE ADDITIVE (3), VARIABLE ADDITIVE AND
C     FIBER (2), OR  VARIABLE ADDITIVE, FIBER, AND FLOW (1)
C     FOR INITIAL TESTS, FLOWS ARE CONSTANT SO (2) SHOULD BE USED
C
      TYPE=NQ(1)
      IN=NQ(2)
      N=NQ(3)
      K=N+3
      GO TO (1,2,3),TYPE
C
C     CALCULATE FLOW DISTRIBUTION
C     NOTE THAT                  THAT ALL TEN VALUES OF OUT MUST BE
C     FILLED IN (WITH ZEROES IF NECESSARY)
    1 DO 4 JJ=4,K
      L=JJ-3
      KK= NQ(JJ)
      Q(KT,KK)=QF(L)*Q(JT,IN)
    4 CONTINUE
C
C     CALCULATE FIBER DISTRIBUTION
    2 IF(Q(JT,IN)) 8,8,7
    7 CF=WF(JT,IN)/Q(JT,IN)
      GO TO 9
    8 CF=0.0
    9 DO 5 JJ=4,K
      KK= NQ(JJ)
      WF(KT,KK)=Q(KT,KK)*CF
    5 CONTINUE
C
C     CALCULATE ADDITIVE DISTRIBUTION
    3 IF(Q(JT,IN)) 11,11,10
   10 CA=WA(JT,IN)/Q(JT,IN)
      GO TO 12
   11 CA=0.0
   12 DO 6 JJ=4,K
      KK= NQ(JJ)
      WA(KT,KK)=Q(KT,KK)*CA
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PCON(J,NC,R,JT,KT,NTANK,NT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NC(6),R(2),NT(4,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     THIS IS A SIMPLE PROPORTIONAL CONTROLLER WITH SELECTIBLE INPUT
C     AND OUTPUT.  THE FIRST PARAMETER (M1 OR N1) SHOWS WHETHER THE
C     SENSOR IS ON A TANK (1) OR A PIPE (2) AND THE SECOND PARAMETER
C     SHOWS WHICH VARIABLE IS SENSED OR CONTROLLED.  FOR THE TANK
C     THE VARIABLES ARE V (1), MF (2), OR MA (3) WHILE FOR THE PIPE
C     THEY ARE Q (1), WF (2), OR WA (3)
C     FOR THE ITERATIVE RELAXATION VERSION OF SIMPAK, STATE OF SYSTEM
C     (JT=1) IS ALWAYS USED FOR V,MF,MA  WHILE RELAXING VALUES (JT,KT)
C     ARE USED FOR THE INTERMEDIATE VARIABLES Q,WF,WA
C
      M1=NC(1)
      M=NC(2)
      M2=NC(3)
      N1=NC(4)
      N=NC(5)
      N2=NC(6)
      SET=R(1)
      GAIN=R(2)
C     LOCATE PROPER INPUT
      CV=CONVAR(M1,M,M2,JT)
C
C     CALCULATE PRESENT VALUE OF ERROR
      ERROR=SET-CV
C     CALCULATE CONTROLLER OUTPUT
C     ANY DESIRED CONTROL ALGORITHM WHICH DOES NOT INVOLVE PREVIOUS VALU
C     MAY BE USED.  IF INTEGRAL CONTROL IS DESIRE, A NEW VECTOR OF STORE
C     PREVIOUS VALUES MUST BE ALLOWED FOR IN MAIN LINE AND SUBROUTINE.
      VC=-GAIN*ERROR
C     VARIABLE TO BE CONTROLLED RESTRICTED TO POSITIVE VALUES
      IF(VC) 19,19,20
   19 VC=0.0
C     NOW LOCATE PROPER OUTPUT
   20 GO TO (11,10),N1
C     OUTPUT VARIABLE IS IN A TANK
   10 GO TO (12,13,14),N2
C     CONTROLLED VARIABLE IS VOLUME (NOT USUALLY CONTROLLABLE DIRECTLY)
   12 V(1,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS OF FIBER IN TANK
   13 MF(1,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS OF ADDITIVE IN TANK
   14 MA(1,N)=VC
      GO TO 18
C
C     OUTPUT IS IN A PIPE
   11 GO TO (15,16,17),N2
C     CONTROLLED VARIABLE IS FLOW RATE
   15 Q(KT,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS RATE OF FIBER
   16 WF(KT,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS RATE OF ADDITIVE
   17 WA(KT,N)=VC
C
   18 CONTINUE
C     BRING ALL FIBER AND ADDITIVE FLOWS OUT OF TANKS UP TO DATE
C     BEFORE RETURN TO MAINLINE
C
      DO 7 JTANK=1,NTANK
      NOUT=NT(4,JTANK)
      IF(V(JT,JTANK)) 21,21,22
   21 CF=0.0
      CA=0.0
      GO TO 23
   22 CF=MF(JT,JTANK)/V(JT,JTANK)
      CA=MA(JT,JTANK)/V(JT,JTANK)
   23 WF(KT,NOUT)=Q(KT,NOUT)*CF
      WA(KT,NOUT)=Q(KT,NOUT)*CA
    7 CONTINUE
      RETURN

      END
```

```
      SUBROUTINE TANK(JTANK,TYPE,DTIME,IN,OUT,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER IN,OUT,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     TYPE CHOOSES WHETHER VOLUME IS VARIABLE (1) OR CONSTANT (2)
C     A SIMPLE LINEAR EXTRAPOLATION OF RATES IS USED.
C
      IF(V(JT,JTANK)) 4,4,3
    3 WF(JT,OUT)=Q(JT,OUT)*MF(JT,JTANK)/V(JT,JTANK)
      WA(JT,OUT)=Q(JT,OUT)*MA(JT,JTANK)/V(JT,JTANK)
      GO TO 5
    4 WF(KT,OUT)=0.0
      WA(KT,OUT)=0.0
    5 GO TO (1,2),TYPE
    1 V(KT,JTANK)=V(JT,JTANK)+DTIME*(Q(JT,IN)-Q(JT,OUT))
    2 MF(KT,JTANK)=MF(JT,JTANK)+DTIME*(WF(JT,IN)-WF(JT,OUT))
      MA(KT,JTANK)=MA(JT,JTANK)+DTIME*(WA(JT,IN)-WA(JT,OUT))
      IF(V(KT,JTANK)) 6,7,7
    6 V(KT,JTANK)=0.0
    7 IF(MF(KT,JTANK)) 8,9,9
    8 MF(KT,JTANK)=0.0
    9 IF(MA(KT,JTANK)) 10,11,11
   10 MA(KT,JTANK)=0.0
   11 CONTINUE
C
C     CALCULATE NEW OUTPUT FLOWS OF FIBER AND ADDITIVE FOR THIS STATE
      WF(KT,OUT)=Q(JT,OUT)*MF(JT,JTANK)/V(JT,JTANK)
      WA(KT,OUT)=Q(JT,OUT)*MA(JT,JTANK)/V(JT,JTANK)
C
C     RETURN NEW VALUES OF V,MF,MA TO STATE VECTOR SIDE OF ARRAY
      V(JT,JTANK)=V(KT,JTANK)
      MF(JT,JTANK)=MF(KT,JTANK)
      MA(JT,JTANK)=MA(KT,JTANK)
      WF(JT,OUT)=WF(KT,OUT)
      WA(JT,OUT)=WA(KT,OUT)
      RETURN
      END
```

```
      FUNCTION CONVAR(N1,N,N2,JT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     THIS ROUTINE SELECTS THE PROPER VARIABLE FROM VECTOR ARRAYS FOR
C     INPUT AND  OUTPUT IN RESPONSE TO A TWO-DIGIT CODE
C 1,1  1,2  1,3     ARE FLOW, FIBER RATE, ADDITIVE RATE FOR PIPES
C 2,1  2,2  2,3     ARE VOLUME, FIBER STORED, ADDITIVE STORED IN TANKS
C     THE SINGLE REAL VALUE OF THE VARIABLE SELECTED IS RETURNED TO THE
C     MAINLINE PROGRAM      FOR ITERATIVE RELAXATION, JT=1 FOR V,MF,MA
C     IS USED ALWAYS, WHILE THE RELAXING VALUES OF Q,WF,WA (JT=JT) ARE
C     USED
C     COPYRIGHT  ROBERT A. HOLM THE INSTITUTE OF PAPER CHEMISTRY 12MAR73
      GO TO (1,2),N1
    1 GO TO (3,4,5),N2
    3 CONVAR=Q(JT,N)
      RETURN
    4 CONVAR=WF(JT,N)
      RETURN
    5 CONVAR=WA(JT,N)
      RETURN
    2 GO TO (6,7,8),N2
    6 CONVAR=V(1,N)
C     THESE VALUES USE THE PRESENT STATE VECTOR FOR THE SYSTEM
C     CONSISTENTLY IN THE DETERMINATION OF THE VALUE OF THE CONTROL
C     VARIABLE TO BE USED
      RETURN
    7 CONVAR=MF(1,N)
      RETURN
    8 CONVAR=MA(1,N)
      RETURN
      END
```

```
      SUBROUTINE MAP(NPIPE,NTANK,PRT,TIME,NTITLE,JT)
      DIMENSION NTITLE(20)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER PRT
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     THIS OUTPUT PROGRAM TABULATES THE VARIABLE OUTPUTS OF EVERY
C     TANK AND PIPE IN THE SYSTEM FOR OCCASSIONAL INSPECTION DURING
C     A SIMULATION RUN  AND AT THE BEGINNING AND END OF EACH SIMULATION
C     COPYRIGHT  ROBERT A. HOLM  THE INSITUTE OF PAPER CHEMISTRY 12MAR73
      WRITE (PRT,100)
  100 FORMAT(1H1)
      WRITE(PRT,112) NTITLE
  112 FORMAT(1H0,20A4)
      WRITE(PRT,101) TIME
  101 FORMAT(1H ,'FULL VARIABLE MAP AT TIME=',F10.4)
      WRITE(PRT,107)
      WRITE(PRT,108) NPIPE
  108 FORMAT(1H ,'THERE ARE',I6,2X,'PIPES')
      WRITE(PRT,109)
  109 FORMAT(1H ,'FLOW RATE')
      WRITE (PRT,104) (Q(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,110)
  110 FORMAT(1H ,'MASS FLOW RATE OF FIBER')
      WRITE (PRT,104) (WF(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,111)
  111 FORMAT(1H ,'MASS FLOW RATE OF ADDITIVE')
      WRITE (PRT,104) (WA(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,107)
  107 FORMAT(1H )
      WRITE (PRT,102) NTANK
  102 FORMAT(1H ,'THERE ARE', I6,2X,'TANKS')
      WRITE (PRT,103)
  103 FORMAT(1H ,'VOLUME')
      WRITE (PRT,104) (V(JT,JJ),JJ=1,NTANK)
  104 FORMAT(1H ,10F8.2)
      WRITE(PRT,105)
  105 FORMAT(1H ,'MASS OF FIBER STORED')
      WRITE (PRT,104) (MF(JT,JJ),JJ=1,NTANK)
      WRITE (PRT,106)
  106 FORMAT(1H ,'MASS OF ADDITIVE STORED')
      WRITE (PRT,104) (MA(JT,JJ),JJ=1,NTANK)
      WRITE(PRT,100)
      RETURN
      END
```

```
      SUBROUTINE HCON(J,NC,R,JT,KT,NTANK,NT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NC(6),R(2),NT(4,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     SEE SUBROUTINE PCON IN SIMPAK FOR ADDITIONAL EXPLANATIONS
C
      M1=NC(1)
      M=NC(2)
      M2=NC(3)
      N1=NC(4)
      N=NC(5)
      N2=NC(6)
      SET=R(1)
      SSOUT=R(2)
C     THIS IS A NONLINEAR (HALF POWER OR SQUARE ROOT) CONTROLLER.  THE
C     OUTPUT IS CALCULATED TO VARY WITH THE SQUARE ROOT OF THE ABSOLUTE
C     VALUE OF THE INPUT.  THE NORMAL USE IS TO CALCULATE A TANK OUTPUT
C     FLOW WHICH IS PROPORTIONAL TO THE SQUARE ROOT OF THE TANK VOLUME
C     THUS SIMULATING AN OUTPUT WEIR, VALVE, OR PIPE UNDER TURBULENT
C     FLOW.  IF THE TANK HAS AN OVERFLOW WIER OR STANDPIPE, ONLY THE
C     ACTIVE VOLUME SHOULD BE COUNTED IN THE VALUE OF 'SET'.
C         FOR THE NORMAL USE(TANK HYDRAULICS) THE VARIABLE SELECTORS
C         SHOULD BE AS FOLLOWS...
C     M1=2    M=TANK NO.          M2=1
C     N1=1    N=OUTPUT FLOW NO.   N2=1
C
C     LOCATE PROPER INPUT
      CV=CONVAR(M1,M,M2,JT)
C
C     CALCULATE CONTROLLER OUTPUT
      VC=SET*(CV/SSOUT)**0.5
C     NOW LOCATE PROPER OUTPUT
   20 GO TO (11,10),N1
   10 GO TO (12,13,14),N2
   12 V(1,N)=VC
      GO TO 18
   13 MF(1,N)=VC
      GO TO 18
   14 MA(1,N)=VC
      GO TO 18
   11 GO TO (15,16,17),N2
   15 Q(KT,N)=VC
      GO TO 18
   16 WF(KT,N)=VC
      GO TO 18
   17 WA(KT,N)=VC
   18 CONTINUE
      DO 7 JTANK=1,NTANK
      NOUT=NT(4,JTANK)
      IF(V(JT,JTANK)) 21,21,22
   21 CF=0.0
      CA=0.0
      GO TO 23
   22 CF=MF(JT,JTANK)/V(JT,JTANK)
      CA=MA(JT,JTANK)/V(JT,JTANK)
   23 WF(KT,NOUT)=Q(KT,NOUT)*CF
      WA(KT,NOUT)=Q(KT,NOUT)*CA
    7 CONTINUE
      RETURN
      END
```

```
      FUNCTION DECODE(N1,N,N2,JT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     THIS ROUTINE SELECTS THE PROPER VARIABLE FROM VECTOR ARRAYS FOR
C     INPUT AND  OUTPUT IN RESPONSE TO A TWO-DIGIT CODE
C 1,1  1,2  1,3    ARE FLOW, FIBER RATE, ADDITIVE RATE FOR PIPES
C 2,1  2,2  2,3    ARE VOLUME, FIBER STORED, ADDITIVE STORED IN TANKS
C     THE SINGLE REAL VALUE OF THE VARIABLE SELECTED IS RETURNED TO THE
C     MAINLINE PROGRAM
C     COPYRIGHT  ROBERT A. HOLM THE INSTITUTE OF PAPER CHEMISTRY 12MAR73
      GO TO (1,2),N1
    1 GO TO (3,4,5),N2
    3 DECODE=Q(JT,N)
      RETURN
    4 DECODE=WF(JT,N)
      RETURN
    5 DECODE=WA(JT,N)
      RETURN
    2 GO TO (6,7,8),N2
    6 DECODE=V(JT,N)
      RETURN
    7 DECODE=MF(JT,N)
      RETURN
    8 DECODE=MA(JT,N)
      RETURN
      END
```

```
      SUBROUTINE NAVEL(NT,NTANK,PRT)
C     SUBROUTINE FOR TABULATING TIME CONSTANTS FOR SIMPAK SIMULATOR
C     ROBERT A. HOLM   COPYRIGHT (C)  JULY 25, 1973
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75),NT(4,75)
      INTEGER CRD,PRT,PCH
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      INTEGER IN,OUT
      WRITE(PRT,101)
  101 FORMAT(1H ,'TIME CONSTANTS FOR IN, OUT, AND NET FLOWS')
      WRITE(PRT,102)
  102 FORMAT(1H ,1X,'TANK',3X,'IN',2X,'OUT',8X,'IN',7X,'OUT',12X,'NET')
      DO 1 JJ=1,NTANK
      IF(V(1,JJ)) 2,2,3
    2 TCIN= 0.0
      TCOUT= 0.0
      TCNET= 0.0
      GO TO 4
    3 IN= NT(3,JJ)
      OUT= NT(4,JJ)
      TCIN= V(1,JJ)/Q(1,IN)
      TCOUT= V(1,JJ)/Q(1,OUT)
      TCNET= V(1,JJ)/(Q(1,OUT)-Q(1,IN))
    4 WRITE(PRT,103)  JJ,IN,OUT,TCIN,TCOUT,TCNET
  103 FORMAT(1H ,3I5,2F10.5,F15.5)
    1 CONTINUE
      WRITE(PRT,100)
  100 FORMAT(1H1)
      RETURN
      END
```

```
      SUBROUTINE LINE(TIME,NOUT,NPRT1,NPRT2,NPRT3,PRT,JT)
      DIMENSION  NPRT1(1),NPRT2(1),NPRT3(1),VAR(7)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER PRT
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
C     THIS SUBROUTINE LOCATES THE SELECTED SEVEN VARIABLES FOR OUTPUT AN
C     PRINTS THEM IN SEVEN COLUMN FORMAT WITH*TIME*IN THE LEADING EIGHTH
C     COLUMN      THE INSTITUTE OF PAPER CHEMISTRY (C) R A HOLM  12 MAR
C     CHECK FOR NOUT .GT. 7
      IF(NOUT-7) 101,101,102
102   WRITE(6,9001)
9001  FORMAT(' MORE THAN 7 OUTPUTS, JOB TERMINATED')
      CALL EXIT
101   DO 1 JJ=1,NOUT
      VAR(JJ)=DECODE(NPRT1(JJ),NPRT2(JJ),NPRT3(JJ),JT)
    1 CONTINUE
      WRITE(PRT,100) TIME,(VAR(JJ),JJ=1,NOUT)
      WRITE(1,9002) TIME,(VAR(I),I=1,NOUT)
9002  FORMAT(20A4)
C     NO MORE THAN SEVEN VARIABLES CAN BE PRINTED
  100 FORMAT(1H ,F10.1,7F10.2)
      RETURN
      END
```

APPENDIX II

LISTING OF THE IMPROVED SIMPAK PROGRAM

This appendix contains a listing of the revised SIMPAK program (main-line and subroutines) used in the Sartell mill (fine paper) system.

```
C      SIMPAK MAINLINE FOR SIMULATION OF MILL WATER SYSTEMS
C      ROBERT A. HOLM  THE INSTITUTE OF PAPER CHEMISTRY
C      COPYRIGHT 11 MAR 73
C      SIMPAK IS STILL IN THE DEVELOPMENT PHASE--CODING IS NOT
C      GUARANTEED TO WORK ON MACHINES OTHER THAN THE IBM 360/44
C      USING THE RAX OPERATING SYSTEM
C      PLEASE REPORT ANY CODING ERRORS TO PETE PARKER AT THE INSTITUTE
C      OF PAPER CHEMISTRY,APPLETON, WISCONSIN 414-734-9251
C      MODIFIED FOR TAPE OR DISK OUTPUT 12/28/73 J Y HUNG
C      SPECIAL TAPE OR DISK OUTPUT IS WRITTEN TO DEVICE 1
C      OTHER DEVICES ARE STANDARD
C      READER=5   PRINTER=6   PUNCH=7
       DIMENSION Q(2,400),WF(2,400),WA(2,400)
       DIMENSION V(2,75),MF(2,75),MA(2,75),NT(4,75)
       DIMENSION NM(14,100)
       DIMENSION NS(5,50),RS(3,50)
       DIMENSION ND(14,50),RD(10,50)
       DIMENSION NPC(7,50),RPC(2,50)
       DIMENSION NPRT1(7),NPRT2(7),NPRT3(7),NTITLE(20)
       INTEGER CRD,PRT,PCH,A(7,8)
       REAL MF,MA
       COMMON Q,WF,WA,V,MF,MA
       COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
       COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C      THESE DIMENSION VARIABLES ARE INPUT TO THE CALL SUBROUTINES FOR
C      EACH MIXER, SEPARATOR, DISTRIBUTOR, CONTROLLER, AND TANK.  MAXIMUM
C      DIMENSION CAN BE CHANGED TO FIT THE SYSTEM TO BE SIMULATED OR
C      COMPUTER MEMORY AVAILABLE.    CAN PUT IN REPEATED CALLS, WITH
C      EXPLICIT STATEMENT OF EACH INPUT CONNECTION IN PLACE OF THESE
C      MATRICES.   Q,WF,WA,V,MF,MA  MUST REMAIN VECTORS, HOWEVER
C
       CALL WHEN
       CRD= 5
       PRT= 6
       PCH= 2
C
C      ZERO ALL DATA POSITIONS
C
       DO 15 KK=1,2
       DO 1 JJ=1,400
       Q(KK,JJ)=0.0
       WF(KK,JJ)=0.0
       WA(KK,JJ)=0.0
     1 CONTINUE
       DO 2 JJ=1,75
       V(KK,JJ)=0.0
       MF(KK,JJ)=0.0
       MA(KK,JJ)=0.0
     2 CONTINUE
    15 CONTINUE
       NMIX=0
       NSEP=0
       NDIST=0
       NPCON=0
       NTANK=0
       NPIPE=0
       KMIX=0
       KSEP=0
       KDIS=0
       JT= 1
       KT= 2
C
       READ(CRD,1001) NTITLE
  1001 FORMAT(20A4)
C
C      INPUT FULL SYSTEM CONFIGURATION AND PARAMETERS
C
C      THE SYSTEM MAY BE GROUPED INTO FUNCTIONAL AREAS OR BLOCKS
C      ANY NUMBER OF IDENTIFYING CARDS   (WITH 999 IN FIRST THREE COLUMNS
C      MAY BE INSERTED BEFORE EACH SET OF MIXERS TO IDENTIFY THAT BLOCK
C      EACH BLOCK MUST CONTAIN MIX,SEP,DIST,PCON,TANK, AND PIPE COUNTS
C      WITH SOME COUNTS ZERO IF THAT SORT OF UNIT IS NOT USED IN THAT
C      BLOCK
C
       READ(CRD,1004) NGRP
  1004 FORMAT(I2)
C
       DO 50 NG=1,NGRP
C
```

```
C       CHECK FOR 999 COMMENT CARDS PRECEDING MIXER IDENTIFICATION
   51   READ(CRD,1000) NMIXG
        IF(NMIXG-999) 52,51,51
 1000   FORMAT(I3)
   52   NSMIX=NMIX+1
        NMIX=NMIX+NMIXG
        IF(NMIXG)1021,1021,1020
 1020   DO 1006 JJ=NSMIX,NMIX
        READ(CRD,1007) (NM(KK,JJ),KK=1,14)
 1006   CONTINUE
 1007   FORMAT(1X,I3,I2,I4,I3,10I4)
C
 1021   READ(CRD,1000) NSEPG
        NSSEP=NSEP+1
        NSEP=NSEP+NSEPG
        IF(NSEPG)1023,1023,1022
 1022   DO 1005 JJ=NSSEP,NSEP
        READ(CRD,1008) (NS(KK,JJ),KK=1,5),(RS(KK,JJ),KK=1,3)
 1008   FORMAT(1X,I3,I2,3I4,3F6.3)
 1005   CONTINUE
C
 1023   READ(CRD,1000) NDISTG
        NSDIS=NDIST+1
        NDIST=NDIST+NDISTG
        IF(NDISTG)1025,1025,1024
 1024   DO 1011 JJ=NSDIS,NDIST
        READ(CRD,1012) (ND(KK,JJ),KK=1,4)
 1012   FORMAT(1X,I3,I2,I4,I3)
        READ(CRD,1016) (ND(KK,JJ),KK=5,14)
 1016   FORMAT(I5,9I6)
        READ(CRD,1017) (RD(KK,JJ),KK=1,10)
 1017   FORMAT(F5.3,9F6.3)
 1011   CONTINUE
C
 1025   READ(CRD,1000) NPCONG
        NSCON=NPCON+1
        NPCON=NPCON+NPCONG
        IF(NPCONG)1027,1027,1026
 1026   DO 1018 JJ=NSCON,NPCON
        READ(CRD,1019) (NPC(KK,JJ),KK=1,7),(RPC(KK,JJ),KK=1,2)
 1019   FORMAT(1X,I3,2(I2,I4,I2),F10.2,F9.2)
 1018   CONTINUE
C
 1027   READ(CRD,1000) NTANKG
        NSTAN=NTANK+1
        NTANK=NTANK+NTANKG
        IF(NTANKG)1029,1029,1028
 1028   DO 1030 JJ=NSTAN,NTANK
        READ(CRD,1031) (NT(KK,JJ),KK=1,4),V(JT,JJ),MF(JT,JJ),MA(JT,JJ)
 1031   FORMAT(1X,I3,I2,2I4,3F10.2)
 1030   CONTINUE
C
 1029   READ(CRD,1000) NPIPEG
        NSPIP=NPIPE+1
        NPIPE=NPIPE+NPIPEG
        IF(NPIPEG)1033,1033,1032
 1033   WRITE(PRT,1034)
 1034   FORMAT(1H ,'WHY ARE THERE NO PIPES...')
        GO TO 1035
 1032   DO 1035 JJ=NSPIP,NPIPE
        READ(CRD,1036) K,Q(JT,K),WF(JT,K),WA(JT,K)
 1036   FORMAT(1X,I3,F10.2,2F9.2)
 1035   CONTINUE
C
   50   CONTINUE
C       UNTIL ALL GROUPS HAVE BEEN READ
C
C       END OF SYSTEM INPUT
C
C       SET NUMBER OF DESIRED PRINTED OUTPUTS AND THEIR IDENTITY
        READ(CRD,1013) NOUT
 1013   FORMAT(I1)
        DO 1014 JJ=1,NOUT
        READ(CRD,1015) NPRT1(JJ),NPRT2(JJ),NPRT3(JJ),(A(JJ,K),K=1,8)
 1015   FORMAT(I1,I4,I2,8A4)
 1014   CONTINUE
C
C       SET TIME STEP, PRINT INTERVAL, MAP INTERVAL, AND END POINT
        READ(CRD,1010) DTIME
```

```
      READ(CRD,1010) DPRT
      READ(CRD,1010) DMAP
      READ(CRD,1010) TFINAL
 1010 FORMAT(F10.4)
      NPRT=(DPRT/DTIME)+0.5
      NMAP=(DMAP/DPRT)+0.5
      NSTOP=(TFINAL/DMAP)+0.5
      TIME=0.0
      WRITE(PRT,1003) NTITLE
 1003 FORMAT(1H ,20A4)
      WRITE(PRT,3000) DTIME,DPRT,DMAP,TFINAL
 3000 FORMAT(1H ,2X,'DTIME =',F8.4,/,3X,'DPRT  =',F8.4,/,
     1           3X,'DMAP  =',F8.4,/,3X,'TFINAL=',F8.4)
      WRITE(PRT,1002) (NPRT1(J),NPRT2(J),NPRT3(J),J=1,NOUT)
 1002 FORMAT(1H ,'OUTPUT CODES ARE',7(I3,I4,I2))
C     WRITE TO TAPE N ITEMS AND OUTPUT CODES
      NTAPE=NSTOP*NMAP
      WRITE(1,9001) NOUT,NTAPE
 9001 FORMAT(8A4)
      DO 170 J=1,NOUT
  170 WRITE(1,9002)  NPRT1(J),NPRT2(J),NPRT3(J),(A(J,K),K=1,8)
 9002 FORMAT(3A4/8A4)
C
C     SET ALL VARIABLES EQUAL FOR PRESENT TIME AND TIME + DTIME.
C     THIS WILL COVER ALL CONSTANT INPUTS FOR CONTINUED CALCULATIONS
C     AND ANY THAT ARE NOT CONSTANT WILL SIMPLY BE OVERLAID
      DO 18 JJ=1,NPIPE
      Q(KT,JJ)=Q(JT,JJ)
      WF(KT,JJ)=WF(JT,JJ)
      WA(KT,JJ)=WA(JT,JJ)
   18 CONTINUE
      DO 19 JJ=1,NTANK
      V(KT,JJ)=V(JT,JJ)
      MF(KT,JJ)=MF(JT,JJ)
      MA(KT,JJ)=MA(JT,JJ)
   19 CONTINUE
      CALL CONF
      CALL SORT
C
C           START  THE SYSTEM AT PROPER EQUILIBRIUM FOR ARBITRARY
C     INITIAL STATE VECTOR OF TANK VOLUMES
      INIT=1
      CALL MAP(NPIPE,NTANK,PRT,-1.0,NTITLE,JT)
      GO TO 35
   36 CONTINUE
      INIT=2
      CALL MAP(NPIPE,NTANK,PRT,0.0,NTITLE,JT)
      CALL NAVEL(NT,NTANK,PRT)
C
C
C     MAIN RETURN POINT
C
      DO 12 LLL=1,NSTOP
      DO 7 KKK=1,NMAP
      DO 3 JJJ=1,NPRT
C
C
      KTR=0
C     IF(NTANK) 33,33,32
   32 DO 34 J=1,NTANK
      CALL TANK(J,NT(2,J),DTIME,NT(3,J),NT(4,J),JT,KT)
   34 CONTINUE
   35 NEXT=NCON
   33 I=IORDR(NEXT)
      J=MTRX(NEXT,7)
      ITYPE=MTRXI(NEXT)
       GO TO (25,28,29,30,30,30),ITYPE
   30 CONTINUE
       GO TO 20
   29 CALL DIST(J,ND(2,J),RD(1,J),JT,KT)
       GO TO 20
   28 CALL SEP(J,NS(2,J),RS(1,J),JT,KT)
       GO TO 20
   25 CALL MIX(J,NM(2,J),JT,KT)
   20 IF(NEXT-NLIST) 21,22,23
   21 NEXT=NEXT+1
       GO TO 33
   23 CONTINUE
      CALL EXIT
   22 CONTINUE
C     KTR=KTR+1
```

```
C     IF(KTR-1) 38,32,38
C     CALL MAP(NPIPE,NTANK,PRT,34.0,NTITLE,JT)
C
   38 IF(JT-1) 16,16,17
   16 JT= 2
      KT= 1
      GO TO 27
   17 JT= 1
      KT= 2
C
   27 CONTINUE
      IF(INIT-1) 36,36,37
   37 CONTINUE
C
      RNDT=JJJ+NPRT*(KKK-1)+NMAP*NPRT*(LLL-1)
      TIME=DTIME*RNDT
    3 CONTINUE
      IF(JT-1) 301,300,301
  300 CALL LINE(TIME,NOUT,NPRT1,NPRT2,NPRT3,PRT,JT)
      GO TO 7
  301 CALL LINE(TIME,NOUT,NPRT1,NPRT2,NPRT3,PRT,KT)
    7 CONTINUE
      IF(JT-1) 306,305,306
  305 CALL MAP(NPIPE,NTANK,PRT,TIME,NTITLE,JT)
      GO TO 12
  306 CALL MAP(NPIPE,NTANK,PRT,TIME,NTITLE,KT)
   12 CONTINUE
C     CALL NAVEL(NT,NTANK,PRT)
      WRITE(PCH,998) NTANK
  998 FORMAT(I3,' TANKS')
  999 FORMAT(I3,' PIPES')
      DO 1037 J=1,NTANK
      WRITE(PCH,1038) (NT(K,J),K=1,4),V(1,J),MF(1,J),MA(1,J)
 1037 CONTINUE
 1038 FORMAT('T',I3,I2,2I4,3F10.2)
      WRITE(PCH,999) NPIPE
      DO 1039 J=1,NPIPE
      WRITE(PCH,1040) J,Q(1,J),WF(1,J),WA(1,J)
 1039 CONTINUE
 1040 FORMAT('P',I3,F10.2,2F9.2)
C     END THE TAPE FILE
      END FILE 1
      CALL EXIT
      END
```

```
      SUBROUTINE MIX(J,IN,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION IN(13)
      INTEGER OUT,N,IN,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON, NEXT,NEQ,NOD
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY,COPYRIGHT11MAR73
C     TYPE SPECIFIES WHICH THINGS MAY CHANGE FOR THIS SIMULATION
C  (1)EVERYTHING   (2)FIBER AND ADDITIVE, BUT NOT FLOW   (3)ADDITIVE ONLY
C     SKIPPING CALCULATIONS SHOULD SPEED UP THE CALCULATION AND IMPROVE
C     ITS ACCURACY.  FOR INITIAL  TESTS AT CONSTANT FLOW, TYPE=2
C
      TYPE=IN(1)
      OUT=IN(2)
      N=IN(3)
      K=N+3
C     TESTING
C     WRITE(6,100) (IN(JJ),JJ=1,13)
C 100 FORMAT(1X,' INS = ', 13I5)
      GO TO (1,2,3),TYPE
C     ADD UP TOTAL FLOW
    1 QD=0.0
      DO 4 JJ=4,K
      KK=IN(JJ)
      QD=QD+Q(JT,KK)
    4 CONTINUE
      Q(KT,OUT)=QD
C
    2 WFD=0.0
C     ADD UP TOTAL FIBER RATE
      DO 5 JJ=4,K
      KK=IN(JJ)
      WFD=WFD+WF(JT,KK)
    5 CONTINUE
      WF(KT,OUT)=WFD
C
C     ADD UP TOTAL ADDITIVE RATE
    3 WAD=0.0
      DO 6 JJ=4,K
      KK=IN(JJ)
      WAD=WAD+WA(JT,KK)
    6 CONTINUE
      WA(KT,OUT)=WAD
C     WRITE(6,101) Q(KT,OUT),WF(KT,OUT),WA(KT,OUT)
C 101 FORMAT(1X,'QOUT=',F10.2,'WF=',F10.2,'WA=',F10.2)
      RETURN
      END
```

```
      SUBROUTINE SEP(J,N,R,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION N(4),R(3)
      INTEGER IN,REJ,ACC,TYPE
      REAL MF,MA
      REAL KF
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     NOTE THAT RF IS FRACTIONAL RETENTION OF SOLIDS IN REJ(ECTS) LINE
C     AND AQ IS FRACTIONAL PASS-THRU OF FLOW VOLUME TO ACC(EPTS) LINE
C
C     TYPE SHOWS WHETHER FIBER RATES (TYPE 3) OR VOLUMETRIC FLOWS (TYPE
C     2) ARE CONSTANT, OR ALL ARE VARIABLE (TYPE1)
C     FOR INITIAL TESTS, TYPE=2
      TYPE=N(1)
      IN=N(2)
      REJ=N(3)
      ACC=N(4)
      RF=R(1)
      AQ=R(2)
      KF=R(3)
C     WRITE(6,100) (N(JJ),JJ=1,4),(R(II),II=1,3)
C 100 FORMAT(1X,'NS=',4I5,'RS=',3F10.2)
C
      GO TO (1,2,3),TYPE
C     CALCULATE VOLUMETRIC FLOW SEPARATION
    1 Q(KT,REJ)=Q(JT,IN)*(1.0-AQ)
      Q(KT,ACC)=Q(JT,IN)-Q(KT,REJ)
C
C     CALCULATE FIBER MASS FLOW SEPARATION
    2 WF(KT,REJ)=WF(JT,IN)*RF
      WF(KT,ACC)=WF(JT,IN)-WF(KT,REJ)
C
C     CALCULATE BALANCE OF ADDITIVE SORBED ON FIBER
C     IF PERFECTLY SOLUBLE AND NOT ABSORBED, KF=0.0
    3 DENOM=Q(JT,IN)+KF*WF(JT,IN)
      IF(DENOM) 8,8,7
    7 CAW=WA(JT,IN)/DENOM
      WAF=KF*CAW
      GO TO 9
    8 CAW=0.0
      WAF=0.0
C     CALCULATE TOTAL DISSOLVED AND SORBED ADDITIVE LEAVING AT EACH PIPE
    9 WA(KT,REJ)=Q(KT,REJ)*CAW+WF(KT,REJ)*WAF
      WA(KT,ACC)=Q(KT,ACC)*CAW+WF(KT,ACC)*WAF
C     WRITE(6,101)   Q(KT,REJ),Q(KT,ACC)
C101  FORMAT(1X, 'QREJ= ',F10.2,' QACC= ',F10.2)
      RETURN
      END
```

```
      SUBROUTINE DIST(J,NQ,QF,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NQ(13),QF(10)
      INTEGER OUT,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     TYPE SIGNIFIES VARIABLE ADDITIVE (3), VARIABLE ADDITIVE AND
C     FIBER (2), OR  VARIABLE ADDITIVE, FIBER, AND FLOW (1)
C     FOR INITIAL TESTS, FLOWS ARE CONSTANT SO (2) SHOULD BE USED
C
      TYPE=NQ(1)
      IN=NQ(2)
      N=NQ(3)
      K=N+3
C
C     WRITE(6,100) (NQ(JJ),JJ=1,13)
C100  FORMAT(1X,' NQS= ',13I5)
C     WRITE(6,101) (QF(II),II=1,10)
C101  FORMAT(1X,' QFS= ',10F6.2)
      GO TO (1,2,3),TYPE
C
C     CALCULATE FLOW DISTRIBUTION
C     NOTE THAT               THAT ALL TEN VALUES OF OUT MUST BE
C     FILLED IN (WITH ZEROES IF NECESSARY)
    1 DO 4 JJ=4,K
      L=JJ-3
      KK= NQ(JJ)
      Q(KT,KK)=QF(L)*Q(JT,IN)
C     WRITE(6,102) Q(KT,KK)
C102  FORMAT(1X,'QSPLT=',5X,F10.2)
    4 CONTINUE
C
C     CALCULATE FIBER DISTRIBUTION
    2 IF(Q(JT,IN)) 8,8,7
    7 CF=WF(JT,IN)/Q(JT,IN)
      GO TO 9
    8 CF=0.0
    9 DO 5 JJ=4,K
      KK= NQ(JJ)
      WF(KT,KK)=Q(KT,KK)*CF
    5 CONTINUE
C
C     CALCULATE ADDITIVE DISTRIBUTION
    3 IF(Q(JT,IN)) 11,11,10
   10 CA=WA(JT,IN)/Q(JT,IN)
      GO TO 12
   11 CA=0.0
   12 DO 6 JJ=4,K
      KK= NQ(JJ)
      WA(KT,KK)=Q(KT,KK)*CA
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PCON(J,NC,R,JT,KT,NTANK,NT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NC(6),R(2),NT(4,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTEG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     THIS IS A SIMPLE PROPORTIONAL CONTROLLER WITH SELECTIBLE INPUT
C     AND OUTPUT.  THE FIRST PARAMETER (M1 OR N1) SHOWS WHETHER THE
C     SENSOR IS ON A TANK (1) OR A PIPE (2) AND THE SECOND PARAMETER
C     SHOWS WHICH VARIABLE IS SENSED OR CONTROLLED.  FOR THE TANK
C     THE VARIABLES ARE V (1), MF (2), OR MA (3) WHILE FOR THE PIPE
C     THEY ARE Q (1), WF (2), OR WA (3)
C     FOR THE ITERATIVE RELAXATION VERSION OF SIMPAK, STATE OF SYSTEM
C     (JT=1) IS ALWAYS USED FOR V,MF,MA  WHILE RELAXING VALUES (JT,KT)
C     ARE USED FOR THE INTERMEDIATE VARIABLES Q,WF,WA
C
      M1=NC(1)
      M=NC(2)
      M2=NC(3)
      N1=NC(4)
      N=NC(5)
      N2=NC(6)
      SET=R(1)
      GAIN=R(2)
C     LOCATE PROPER INPUT
      CV=CONVAR(M1,M,M2,JT)
C
C     CALCULATE PRESENT VALUE OF ERROR
      ERROR=SET-CV
C     CALCULATE CONTROLLER OUTPUT
C     ANY DESIRED CONTROL ALGORITHM WHICH DOES NOT INVOLVE PREVIOUS VALU
C     MAY BE USED.  IF INTEGRAL CONTROL IS DESIRE, A NEW VECTOR OF STORE
C     PREVIOUS VALUES MUST BE ALLOWED FOR IN MAIN LINE AND SUBROUTINE.
      VC=-GAIN*ERROR
C     VARIABLE TO BE CONTROLLED RESTRICTED TO POSITIVE VALUES
      IF(VC) 19,19,20
   19 VC=0.0
C     NOW LOCATE PROPER OUTPUT
   20 GO TO (11,10),N1
C     OUTPUT VARIABLE IS IN A TANK
   10 GO TO (12,13,14),N2
C     CONTROLLED VARIABLE IS VOLUME (NOT USUALLY CONTROLLABLE DIRECTLY)
   12 V(1,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS OF FIBER IN TANK
   13 MF(1,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS OF ADDITIVE IN TANK
   14 MA(1,N)=VC
      GO TO 18
C
C     OUTPUT IS IN A PIPE
   11 GO TO (15,16,17),N2
C     CONTROLLED VARIABLE IS FLOW RATE
   15 Q(KT,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS RATE OF FIBER
   16 WF(KT,N)=VC
      GO TO 18
C     CONTROLLED VARIABLE IS MASS RATE OF ADDITIVE
   17 WA(KT,N)=VC
C
   18 CONTINUE
C     BRING ALL FIBER AND ADDITIVE FLOWS OUT OF TANKS UP TO DATE
C     BEFORE RETURN TO MAINLINE
C
      DO 7 JTANK=1,NTANK
      NOUT=NT(4,JTANK)
      IF(V(JT,JTANK)) 21,21,22
   21 CF=0.0
      CA=0.0
      GO TO 23
   22 CF=MF(JT,JTANK)/V(JT,JTANK)
      CA=MA(JT,JTANK)/V(JT,JTANK)
   23 WF(KT,NOUT)=Q(KT,NOUT)*CF
      WA(KT,NOUT)=Q(KT,NOUT)*CA

    7 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TANK(JTANK,TYPE,DTIME,IN,OUT,JT,KT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER IN,OUT,TYPE
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     ROBERT A. HOLM, THE INSTITUTE OF PAPER CHEMISTRY, COPYRIGHT11MAR73
C     TYPE CHOOSES WHETHER VOLUME IS VARIABLE (1) OR CONSTANT (2)
C     A SIMPLE LINEAR EXTRAPOLATION OF RATES IS USED.
C
      IF(V(JT,JTANK)) 4,4,3
    3 WF(JT,OUT)=Q(JT,OUT)*MF(JT,JTANK)/V(JT,JTANK)
      WA(JT,OUT)=Q(JT,OUT)*MA(JT,JTANK)/V(JT,JTANK)
      GO TO 5
    4 WF(KT,OUT)=0.0
      WA(KT,OUT)=0.0
    5 GO TO (1,2),TYPE
    1 V(KT,JTANK)=V(JT,JTANK)+DTIME*(Q(JT,IN)-Q(JT,OUT))
    2 MF(KT,JTANK)=MF(JT,JTANK)+DTIME*(WF(JT,IN)-WF(JT,OUT))
      MA(KT,JTANK)=MA(JT,JTANK)+DTIME*(WA(JT,IN)-WA(JT,OUT))
      IF(V(KT,JTANK)) 6,7,7
    6 V(KT,JTANK)=0.0
    7 IF(MF(KT,JTANK)) 8,9,9
    8 MF(KT,JTANK)=0.0
    9 IF(MA(KT,JTANK)) 10,11,11
   10 MA(KT,JTANK)=0.0
   11 CONTINUE
C
C     CALCULATE NEW OUTPUT FLOWS OF FIBER AND ADDITIVE FOR THIS STATE
      WF(KT,OUT)=Q(JT,OUT)*MF(KT,JTANK)/V(JT,JTANK)
      WA(KT,OUT)=Q(JT,OUT)*MA(KT,JTANK)/V(JT,JTANK)
C
C     RETURN NEW VALUES OF V,MF,MA TO STATE VECTOR SIDE OF ARRAY
      V(JT,JTANK)=V(KT,JTANK)
      MF(JT,JTANK)=MF(KT,JTANK)
      MA(JT,JTANK)=MA(KT,JTANK)
      WF(JT,OUT)=WF(KT,OUT)
      WA(JT,OUT)=WA(KT,OUT)
      RETURN
      END
```

```
      FUNCTION CONVAR(N1,N,N2,JT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     THIS ROUTINE SELECTS THE PROPER VARIABLE FROM VECTOR ARRAYS FOR
C     INPUT AND  OUTPUT IN RESPONSE TO A TWO-DIGIT CODE
C 1,1  1,2  1,3     ARE FLOW, FIBER RATE, ADDITIVE RATE FOR PIPES
C 2,1  2,2  2,3     ARE VOLUME, FIBER STORED, ADDITIVE STORED IN TANKS
C     THE SINGLE REAL VALUE OF THE VARIABLE SELECTED IS RETURNED TO THE
C     MAINLINE PROGRAM      FOR ITERATIVE RELAXATION, JT=1 FOR V,MF,MA
C     IS USED ALWAYS, WHILE THE RELAXING VALUES OF Q,WF,WA (JT=JT) ARE
C     USED
C     COPYRIGHT  ROBERT A. HOLM THE INSTITUTE OF PAPER CHEMISTRY 12MAR73
      GO TO (1,2),N1
    1 GO TO (3,4,5),N2
    3 CONVAR=Q(JT,N)
      RETURN
    4 CONVAR=WF(JT,N)
      RETURN
    5 CONVAR=WA(JT,N)
      RETURN
    2 GO TO (6,7,8),N2
    6 CONVAR=V(1,N)
C     THESE VALUES USE THE PRESENT STATE VECTOR FOR THE SYSTEM
C     CONSISTENTLY IN THE DETERMINATION OF THE VALUE OF THE CONTROL
C     VARIABLE TO BE USED
      RETURN
    7 CONVAR=MF(1,N)
      RETURN
    8 CONVAR=MA(1,N)
      RETURN
      END
```

```
      SUBROUTINE MAP(NPIPE,NTANK,PRT,TIME,NTITLE,JT)
      DIMENSION NTITLE(20)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER PRT
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     THIS OUTPUT PROGRAM TABULATES THE VARIABLE OUTPUTS OF EVERY
C     TANK AND PIPE IN THE SYSTEM FOR OCCASSIONAL INSPECTION DURING
C     A SIMULATION RUN  AND AT THE BEGINNING AND END OF EACH SIMULATION
C     COPYRIGHT  ROBERT A. HOLM  THE INSITUTE OF PAPER CHEMISTRY 12MAR73
      WRITE (PRT,100)
  100 FORMAT(1H1)
      WRITE(PRT,112) NTITLE
  112 FORMAT(1H0,20A4)
      WRITE(PRT,101) TIME
  101 FORMAT(1H ,'FULL VARIABLE MAP AT TIME=',F10.4)
      WRITE(PRT,107)
      WRITE(PRT,108) NPIPE
  108 FORMAT(1H ,'THERE ARE',I6,2X,'PIPES')
      WRITE(PRT,109)
  109 FORMAT(1H ,'FLOW RATE')
      WRITE (PRT,104) (Q(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,110)
  110 FORMAT(1H ,'MASS FLOW RATE OF FIBER')
      WRITE (PRT,104) (WF(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,111)
  111 FORMAT(1H ,'MASS FLOW RATE OF ADDITIVE')
      WRITE (PRT,104) (WA(JT,JJ),JJ=1,NPIPE)
      WRITE(PRT,107)
  107 FORMAT(1H )
      WRITE (PRT,102) NTANK
  102 FORMAT(1H ,'THERE ARE', I6,2X,'TANKS')
      WRITE (PRT,103)
  103 FORMAT(1H ,'VOLUME')
      WRITE (PRT,104) (V(JT,JJ),JJ=1,NTANK)
  104 FORMAT(1H ,10F8.2)
      WRITE(PRT,105)
  105 FORMAT(1H ,'MASS OF FIBER STORED')
      WRITE (PRT,104) (MF(JT,JJ),JJ=1,NTANK)
      WRITE (PRT,106)
  106 FORMAT(1H ,'MASS OF ADDITIVE STORED')
      WRITE (PRT,104) (MA(JT,JJ),JJ=1,NTANK)
      WRITE(PRT,100)
      RETURN
      END
```

```
      SUBROUTINE HCON(J,NC,R,JT,KT,NTANK,NT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      DIMENSION NC(6),R(2),NT(4,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     SEE SUBROUTINE PCON IN SIMPAK FOR ADDITIONAL EXPLANATIONS
C
      M1=NC(1)
      M=NC(2)
      M2=NC(3)
      N1=NC(4)
      N=NC(5)
      N2=NC(6)
      SET=R(1)
      SSOUT=R(2)
C     THIS IS A NONLINEAR (HALF POWER OR SQUARE ROOT) CONTROLLER. THE
C     OUTPUT IS CALCULATED TO VARY WITH THE SQUARE ROOT OF THE ABSOLUTE
C     VALUE OF THE INPUT.  THE NORMAL USE IS TO CALCULATE A TANK OUTPUT
C     FLOW WHICH IS PROPORTIONAL TO THE SQUARE ROOT OF THE TANK VOLUME
C     THUS SIMULATING AN OUTPUT WEIR, VALVE, OR PIPE UNDER TURBULENT
C     FLOW.  IF THE TANK HAS AN OVERFLOW WIER OR STANDPIPE, ONLY THE
C     ACTIVE VOLUME SHOULD BE COUNTED IN THE VALUE OF 'SET'.
C         FOR THE NORMAL USE(TANK HYDRAULICS) THE VARIABLE SELECTORS
C         SHOULD BE AS FOLLOWS...
C     M1=2    M=TANK NO.          M2=1
C     N1=1    N=OUTPUT FLOW NO.   N2=1
C
C     LOCATE PROPER INPUT
      CV=CONVAR(M1,M,M2,JT)
C
C     CALCULATE CONTROLLER OUTPUT
      VC=SET*(CV/SSOUT)**0.5
C     NOW LOCATE PROPER OUTPUT
   20 GO TO (11,10),N1
   10 GO TO (12,13,14),N2
   12 V(1,N)=VC
      GO TO 18
   13 MF(1,N)=VC
      GO TO 18
   14 MA(1,N)=VC
      GO TO 18
   11 GO TO (15,16,17),N2
   15 Q(KT,N)=VC
      GO TO 18
   16 WF(KT,N)=VC
      GO TO 18
   17 WA(KT,N)=VC
   18 CONTINUE
      DO 7 JTANK=1,NTANK
      NOUT=NT(4,JTANK)
      IF(V(JT,JTANK)) 21,21,22
   21 CF=0.0
      CA=0.0
      GO TO 23
   22 CF=MF(JT,JTANK)/V(JT,JTANK)
      CA=MA(JT,JTANK)/V(JT,JTANK)
   23 WF(KT,NOUT)=Q(KT,NOUT)*CF
      WA(KT,NOUT)=Q(KT,NOUT)*CA
    7 CONTINUE
      RETURN
      END
```

```
      FUNCTION DECODE(N1,N,N2,JT)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     THIS ROUTINE SELECTS THE PROPER VARIABLE FROM VECTOR ARRAYS FOR
C     INPUT AND  OUTPUT IN RESPONSE TO A TWO-DIGIT CODE
C 1,1  1,2  1,3    ARE FLOW, FIBER RATE, ADDITIVE RATE FOR PIPES
C 2,1  2,2  2,3    ARE VOLUME, FIBER STORED, ADDITIVE STORED IN TANKS
C     THE SINGLE REAL VALUE OF THE VARIABLE SELECTED IS RETURNED TO THE
C     MAINLINE PROGRAM
C     COPYRIGHT  ROBERT A. HOLM THE INSTITUTE OF PAPER CHEMISTRY 12MAR73
      GO TO (1,2),N1
    1 GO TO (3,4,5),N2
    3 DECODE=Q(JT,N)
      RETURN
    4 DECODE=WF(JT,N)
      RETURN
    5 DECODE=WA(JT,N)
      RETURN
    2 GO TO (6,7,8),N2
    6 DECODE=V(JT,N)
      RETURN
    7 DECODE=MF(JT,N)
      RETURN
    8 DECODE=MA(JT,N)
      RETURN
      END
```

```
      SUBROUTINE NAVEL(NT,NTANK,PRT)
C     SUBROUTINE FOR TABULATING TIME CONSTANTS FOR SIMPAK SIMULATOR
C     ROBERT A. HOLM    COPYRIGHT (C)   JULY 25, 1973
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75),NT(4,75)
      INTEGER CRD,PRT,PCH
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
      INTEGER IN,OUT
      WRITE(PRT,101)
  101 FORMAT(1H ,'TIME CONSTANTS FOR IN, OUT, AND NET FLOWS')
      WRITE(PRT,102)
  102 FORMAT(1H ,1X,'TANK',3X,'IN',2X,'OUT',8X,'IN',7X,'OUT',12X,'NET')
      DO 1 JJ=1,NTANK
      IF(V(1,JJ)) 2,2,3
    2 TCIN= 0.0
      TCOUT= 0.0
      TCNET= 0.0
      GO TO 4
    3 IN= NT(3,JJ)
      OUT= NT(4,JJ)
      TCIN= V(1,JJ)/Q(1,IN)
      TCOUT= V(1,JJ)/Q(1,OUT)
      TCNET= V(1,JJ)/(Q(1,OUT)-Q(1,IN))
    4 WRITE(PRT,103)  JJ,IN,OUT,TCIN,TCOUT,TCNET
  103 FORMAT(1H ,3I5,2F10.5,F15.5)
    1 CONTINUE
      WRITE(PRT,100)
  100 FORMAT(1H1)
      RETURN
      END
```

```
      SUBROUTINE LINE(TIME,NOUT,NPRT1,NPRT2,NPRT3,PRT,JT)
      DIMENSION  NPRT1(1),NPRT2(1),NPRT3(1),VAR(7)
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      INTEGER PRT
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
C     THIS SUBROUTINE LOCATES THE SELECTED SEVEN VARIABLES FOR OUTPUT AN
C     PRINTS THEM IN SEVEN COLUMN FORMAT WITH*TIME*IN THE LEADING EIGHTH
C     COLUMN      THE INSTITUTE OF PAPER CHEMISTRY (C) R A HOLM  12 MAR
C     CHECK FOR NOUT .GT. 7
      IF(NOUT-7) 101,101,102
102   WRITE(6,9001)
9001  FORMAT(' MORE  THAN 7 OUTPUTS, JOB TERMINATED')
      CALL EXIT
101   DO 1 JJ=1,NOUT
      VAR(JJ)=DECODE(NPRT1(JJ),NPRT2(JJ),NPRT3(JJ),JT)
    1 CONTINUE
      WRITE(PRT,100) TIME,(VAR(JJ),JJ=1,NOUT)
      WRITE(1,9002) TIME,(VAR(I),I=1,NOUT)
9002  FORMAT(20A4)
C     NO MORE THAN SEVEN VARIABLES CAN BE PRINTED
  100 FORMAT(1H ,F10.1,7F10.2)
      RETURN
      END
```

```
      SUBROUTINE CONF
C     CONF(3251)
C     CARD ENTRY FOR CONFIGURATION
C     JAMES Y. HUNG    MARCH,31,1975
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
      NBLK=0
 10   READ(5,202) I,J,K,L,M,N,KLAS,ID
 202  FORMAT(8I5)
      IF(I) 150,200,100
C
  30  WRITE(6,203) I,J,K,L,M,N,KLAS,ID
 203  FORMAT(1X,8I5)
      GO TO 10
C
  100 CONTINUE
      IF(MTRX(I,1)) 148,148,147
 147  WRITE(6,207)
 207  FORMAT( '  PREVIOUS SPECIFICATION DELETED ')
C
 148  MTRX(I,1)=KLAS
      MTRX1(I) =KLAS
      MTRX(I,2)=J
      MTRX(I,3)=K
      MTRX(I,4)=L
      MTRX(I,5)=M
      MTRX(I,6)=N
      MTRX(I,7)=ID
      MTRX7(I) =ID
      NBLK=NBLK+1
       GO TO 30
C    ERROR SECTION
 150  WRITE(6,205) I
 205  FORMAT( ' THE SPECIFICATION FOR BLOCK ',I5, ' IS INCORRECT')
      CALL EXIT
C     EXIT FROM THIS SUBROUTINE
 200  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SORT
C     FIRST  PREPARE FOR SORT OPERATION
C     TEST FOR INTEGRAL & INPUT ELEMENTS
C     JAMES Y. HUNG      MARCH 31 1975
C
      DIMENSION Q(2,400),WF(2,400),WA(2,400)
      DIMENSION V(2,75),MF(2,75),MA(2,75)
      REAL MF,MA
      COMMON Q,WF,WA,V,MF,MA
      COMMON MTRX(50,7),IORDR(50),IDLA(5),INTG(20),MTRX1(50),MTRX7(50)
      COMMON NBLK,NLIST,NCON,NEXT,NEQ,NOD
      NOD=0
      NEQ=0
      NCON=1
      IERR=2
C199  FORMAT(' ',7I5)
      DO 11 I=1,NBLK
C     WRITE(6,199)  I,(MTRX(I,J),J=1,6)
      IF(MTRX(I,1)) 11,11,12
C     DELAY ELEMENT
   12 IF(MTRX(I,1)- 6 ) 14,13,14
  13  NOD=NOD+1
      IDLA(NOD) = I
      GO TO  25
  14  CONTINUE
   16 IF(MTRX(I,1)-4)  18,17,18
   17 NEQ=NEQ+1
      INTG(NEQ)=I
      GO TO 25
   18 IF(MTRX(I,1)-5) 20,19,20
   19 IORDR(NCON) = I
      MTRX(NCON,7)=MTRX7(I)
      MTRX1(NCON)=MTRX(I,1)
       NCON=NCON+1
      GO TO 26
   20 CONTINUE
C     SET ELEMENT IDENTIFIER NEGATIVE UNTIL AFTER SORTING
C
   25 MTRX(I,1)=-MTRX(I,1)
   26 CONTINUE
      DO 27 M=2, 6
      LTEST=IABS(MTRX(I,M))
      IF( LTEST ) 27,27,29
  29  IF( MTRX(LTEST,1)) 27,28,27
  200 FORMAT( 1X,I3,10X,I3/)
   28 WRITE(6,200) LTEST,I
   27 CONTINUE
   11 CONTINUE
C
C     PERFORM SORT OPERATION
C
      DO 50 N=NCON,NBLK
  50  IORDR(N)=0
C
      NLIST=NCON-1
  60  DO 51 I=1,NBLK
      IF(MTRX(I,1)) 52,51,51
  52  CONTINUE
      DO 55 M=2,6
      LTEST=IABS(MTRX(I,M))
      IF(LTEST) 53,55,53
   53 CONTINUE
      IF(NOD) 54,54,56
  56  DO 57 N=1,NOD
      IF(LTEST - IDLA(N)) 57,55,57
  57  CONTINUE
   54  CONTINUE
C
      DO 58 N=1,NEQ
      IF(LTEST-INTG(N)) 58,55,58
   58 CONTINUE
      DO 59 N=1,NLIST
      IF(LTEST-IORDR(N)) 59,55,59
  59  CONTINUE
       GO TO 51
  55  CONTINUE
C
  61  NLIST = NLIST + 1
      IORDR(NLIST) = I
```

```
      MTRX(NLIST,7)=MTRX7(I)
      MTRX1(NLIST)=IABS(MTRX(I,1))
      MTRX(I,1) = - MTRX(I,1)
       GO TO 60
   51 CONTINUE
C
C     SORT TEST
C
      DO 65 I=1,NBLK
      IF(MTRX(I,1)) 66,65,65
   66 IERR=1
      MTRX(I,1) = - MTRX(I,1)
      WRITE(6, 201) I
  201 FORMAT(1X,'SORT FAILURE - BLOCK ',I4)
      NLIST = NLIST + 1
      IORDR(NLIST) = I
       GO TO 60
   65 CONTINUE
C
       GO TO (67,68),IERR
      UNSUCCESSFUL SORT
   67 CALL EXIT
C       SUCCESSFUL SORT
   68 WRITE(6,202) NBLK,NLIST,NCON,NEXT,NEQ,NOD
      WRITE(6,203) (IORDR(JJ),MTRX(JJ,7),MTRX1(JJ),JJ=1,NBLK)
  202 FORMAT(1X,   6I5)
  203 FORMAT(1X,3I5)
   69 RETURN
      END
```

APPENDIX III

LISTING OF EXISTING YORK MILL INPUT DATA (INITIAL CONDITION)

This appendix contains a listing of the input data for the York mill (board) at the initial steady state condition.

```
SIMPAK FOR YORK BOARD MILL (ST. REGIS PAPER COMPANY)
01
999                                                                    00040
999  PROJECT 3251  PHASES I&II
999  THIS SIMULATION RUN WITHOUT CONTROLLERS ON EACH TANK
999                                                                    00070
072 MIXERS
M001 1 003 02 001 002
M002 1 004 02 003 005
M003 1 009 02 007 010
M004 1 012 03 009 011 013
M005 1 038 02 039 040
M006 1 039 02 041 042
M007 1 043 02 026 044
M008 1 051 02 052 053
M009 1 053 02 028 054
M010 1 054 02 023 055
M011 1 054 02 047 048
M012 1 048 02 015 049
M013 1 017 02 016 018
M014 1 069 02 062 070
M015 1 074 06 025 031 063 071 072 073
M016 1 067 02 061 066
M017 1 058 03 008 056 057
M018 1 080 02 078 079
M019 1 083 02 081 082
M020 1 085 03 083 084 086
M021 1 090 03 087 089 091
M022 1 095 02 093 096
M023 1 126 02 094 125
M024 1 128 02 126 127
M025 1 133 06 097 130 131 132 134 135
M026 1 140 03 137 139 276
M027 1 144 03 088 119 142
M028 1 148 02 149 146
M029 1 104 02 102 103
M030 1 108 02 106 107
M031 1 139 02 110 150
M032 1 112 02 111 113
M033 1 116 02 114 115
M034 1 118 02 116 117
M035 1 122 03 120 121 123
M036 1 152 02 151 153
M037 1 156 03 154 155 157
M038 1 160 03 158 159 161
M039 1 161 02 186 187
M040 1 183 02 163 182
M041 1 165 02 162 164
M042 1 193 02 192 194
M043 1 191 04 173 188 189 190
M044 1 073 03 172 176 177
M045 1 224 02 223 225
M046 1 198 03 035 196 197
M047 1 197 02 233 234
M048 1 205 02 213 214
M049 1 204 03 202 203 205
M050 1 231 02 219 230
M051 1 217 02 216 218
M052 1 260 02 257 259
```

```
M053 1 236 02 235 237
M054 1 238 02 201 236
M055 1 247 02 246 248
M056 1 253 02 250 252
M057 1 262 02 075 261
M058 1 264 03 263 265 266
M059 1 270 03 232 269 271
M060 1 233 02 268 273
M061 1 280 02 138 279
M062 1 277 03 064 226 258
M063 1 286 02 282 285
M064 1 288 02 287 289
M065 1 297 02 283 286
M066 1 310 03 242 293 309
M067 1 299 03 181 284 298
M068 1 303 03 301 302 304
M069 1 317 02 215 312
M070 1 324 02 322 323
M071 1 326 02 318 325
M072 1 330 02 328 329
050 SEPARATORS
S001 1 046 045 011 0.001 0.999 0.000
S002 1 014 015 016 0.150 0.861 0.000
S003 1 019 020 021 0.724 0.868 0.000
S004 1 020 023 022 1.000 0.727 0.000
S005 1 023 025 024 0.000 0.942 0.000
S006 1 027 028 029 0.000 0.536 0.000
S007 1 029 031 030 0.000 0.859 0.000
S008 1 030 033 032 1.000 0.982 0.000
S009 1 058 005 059 0.000 0.771 0.000
S010 1 085 088 087 0.108 0.939 0.000
S011 1 092 093 094 1.000 0.984 0.000
S012 1 095 098 097 1.000 0.871 0.000
S013 1 098 100 099 1.000 0.899 0.000
S014 1 140 142 141 1.000 0.945 0.000
S015 1 145 146 147 0.002 0.999 0.000
S016 1 148 107 127 1.000 0.815 0.000
S017 1 118 119 120 0.081 0.961 0.000
S018 1 124 096 125 1.000 0.984 0.000
S019 1 191 155 192 1.000 0.923 0.000
S020 1 160 162 163 0.258 0.715 0.000
S021 1 166 168 167 0.794 0.829 0.000
S022 1 168 170 169 1.000 0.776 0.000
S023 1 170 171 172 0.000 0.904 0.000
S024 1 174 175 176 1.000 0.633 0.000
S025 1 175 179 178 1.000 0.963 0.000
S026 1 184 185 186 0.003 1.000 0.000
S027 1 198 199 200 0.001 0.999 0.000
S028 1 206 207 208 0.001 1.000 0.000
S029 1 208 209 210 0.150 0.876 0.000
S030 1 209 215 203 0.005 0.999 0.000
S031 1 210 211 212 1.000 0.721 0.000
S032 1 217 220 219 1.000 0.888 0.000
S033 1 220 221 222 1.000 0.591 0.000
S034 1 239 240 241 0.999 1.000 0.000
S035 1 241 242 243 0.149 0.877 0.000
S036 1 243 244 245 1.000 0.684 0.000
S037 1 247 249 250 1.000 0.888 0.000
S038 1 249 251 252 1.000 0.682 0.000
S039 1 270 273 272 1.000 0.997 0.000
```

```
S040 1 264 268 267 1.000 0.908 0.000
S041 1 290 291 292 0.001 1.000 0.000
S042 1 292 293 294 0.095 0.928 0.000
S043 1 294 295 296 1.000 0.800 0.000
S044 1 299 300 301 0.008 0.002 0.000
S045 1 311 312 304 0.006 0.999 0.000
S046 1 305 307 306 0.001 1.000 0.000
S047 1 306 309 308 0.150 0.877 0.000
S048 1 308 314 313 1.000 0.722 0.000
S049 1 317 319 318 1.000 0.888 0.000
S050 1 319 321 320 1.000 0.545 0.000
031 DISTRIBUTORS
D001 1 037 02
  002    036
0.882 0.117 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D002 1 006 02
  007    008
0.978 0.022 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D003 1 050 02
  047    049
0.057 0.943 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D004 1 024 02
  026    027
0.040 0.960 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D005 1 065 02
  013    066
0.447 0.553 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D006 1 068 02
  057    064
0.264 0.736 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D007 1 060 05
  010    044    061    062    063
0.319 0.220 0.125 0.279 0.053 0.000 0.000 0.000 0.000 0.000
D008 1 033 02
  034    035
0.948 0.052 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D009 1 090 02
  082    092
0.515 0.485 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D010 1 100 02
  101    102
0.908 0.092 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D011 1 136 02
  137    138
0.342 0.658 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D012 1 129 07
   79     86    113    117    130    147    150
0.010 0.258 0.019 0.548 0.125 0.036 0.004 0.000 0.000 0.000
D013 1 143 04
   84     89    121    131
0.449 0.032 0.064 0.455 0.000 0.000 0.000 0.000 0.000 0.000
D014 1 109 02
  110    111
0.006 0.994 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D015 1 122 02
  115    124
0.501 0.499 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D016 1 195 06
  135    157    177    182    187    189
0.175 0.021 0.096 0.313 0.142 0.253 0.000 0.000 0.000 0.000
```

```
D017 1 167 02
 159    188
0.476 0.524 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D018 1 171 02
 173    174
0.006 0.994 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D019 1 179 02
 180    181
0.914 0.086 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D020 1 215 03
 042    151    232
0.867 0.129 0.004 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D021 1 200 02
 201    202
0.248 0.202 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D022 1 227 02
 225    226
0.860 0.140 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D023 1 229 02
 218    228
0.608 0.392 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D024 1 256 02
 257    258
0.708 0.292 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D025 1 254 02
 248    255
0.543 0.457 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D026 1 278 03
 001    234    266
0.012 0.443 0.545 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D027 1 274 03
 052    214    275
0.622 0.258 0.120 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D028 1 281 05
 235    265    282    283    284
0.418 0.226 0.176 0.057 0.123 0.000 0.000 0.000 0.000 0.000
D029 1 331 02
 279    323
0.384 0.616 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D030 1 327 02
 316    328
0.618 0.382 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
D031 1 332 02
 302    329
0.795 0.205 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
000 CONTROLLERS
062 TANKS
T001 2 004 006    5000.00       0.00       0.00    TANK VOLUME ASSUMED
T002 2 012 014    5000.00       0.00       0.00           DITTO
T003 2 017 019    5000.00       0.00       0.00           DITTO
T004 2 021 070    5000.00       0.00       0.00           DITTO
T005 2 069 065    5000.00       0.00       0.00           DITTO
T006 2 067 068    5000.00       0.00       0.00           DITTO
T007 2 060 059    5000.00       0.00       0.00    TANK VOLUME ASSUMED
T008 2 038 037    5000.00       0.00       0.00           DITTO
T009 2 043 040    5000.00       0.00       0.00           DITTO
T010 2 051 050    5000.00       0.00       0.00           DITTO
T011 2 074 075    5000.00       0.00       0.00           DITTO
T012 2 036 076    5000.00       0.00       0.00           DITTO
T013 2 076 077    5000.00       0.00       0.00           DITTO
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T014	2	077	078	5000.00	0.00	0.00	DITTO
T015	2	080	081	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T016	2	144	145	5000.00	0.00	0.00	DITTO
T017	2	141	143	5000.00	0.00	0.00	DITTO
T018	2	128	129	5000.00	0.00	0.00	DITTO
T019	2	133	136	5000.00	0.00	0.00	DITTO
T020	2	104	105	5000.00	0.00	0.00	DITTO
T021	2	105	106	5000.00	0.00	0.00	DITTO
T022	2	108	109	5000.00	0.00	0.00	DITTO
T023	2	112	114	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T024	2	152	154	5000.00	0.00	0.00	DITTO
T025	2	156	158	5000.00	0.00	0.00	DITTO
T026	2	183	184	5000.00	0.00	0.00	DITTO
T027	2	165	166	5000.00	0.00	0.00	DITTO
T028	2	193	195	5000.00	0.00	0.00	DITTO
T029	2	169	194	5000.00	0.00	0.00	DITTO
T030	2	224	231	5000.00	0.00	0.00	DITTO
T031	2	204	206	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T032	2	212	213	5000.00	0.00	0.00	DITTO
T033	2	211	216	5000.00	0.00	0.00	DITTO
T034	2	231	229	5000.00	0.00	0.00	DITTO
T035	2	228	227	5000.00	0.00	0.00	DITTO
T036	2	222	230	5000.00	0.00	0.00	DITTO
T037	2	221	223	5000.00	0.00	0.00	DITTO
T038	2	260	041	5000.00	0.00	0.00	DITTO
T039	2	238	239	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T040	2	245	237	5000.00	0.00	0.00	DITTO
T041	2	244	246	5000.00	0.00	0.00	DITTO
T042	2	255	256	5000.00	0.00	0.00	DITTO
T043	2	253	254	5000.00	0.00	0.00	DITTO
T044	2	251	259	5000.00	0.00	0.00	DITTO
T045	2	262	263	5000.00	0.00	0.00	DITTO
T046	2	267	269	5000.00	0.00	0.00	DITTO
T047	2	272	274	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T048	2	280	281	5000.00	0.00	0.00	DITTO
T049	2	277	278	5000.00	0.00	0.00	DITTO
T050	2	286	287	5000.00	0.00	0.00	DITTO
T051	2	288	290	5000.00	0.00	0.00	DITTO
T052	2	297	289	5000.00	0.00	0.00	DITTO
T053	2	295	153	5000.00	0.00	0.00	DITTO
T054	2	310	311	5000.00	0.00	0.00	DITTO
T055	2	303	305	5000.00	0.00	0.00	TANK VOLUME ASSUMED
T056	2	313	312	5000.00	0.00	0.00	DITTO
T057	2	314	315	5000.00	0.00	0.00	DITTO
T058	2	321	322	5000.00	0.00	0.00	DITTO
T059	2	324	103	5000.00	0.00	0.00	DITTO
T060	2	320	325	5000.00	0.00	0.00	DITTO
T061	2	326	327	5000.00	0.00	0.00	DITTO
T062	2	330	331	5000.00	0.00	0.00	DITTO

332 PIPES

P001	26.14	0.19	0.00
P002	1173.89	231.14	0.00
P003	1200.00	231.33	0.00
P004	1366.40	248.00	0.00
P005	166.37	16.67	0.00
P006	1366.40	248.00	0.00
P007	1336.10	242.50	0.00
P008	30.30	5.50	0.00
P009	1514.80	242.50	0.00
P010	178.70	0.00	0.00

P011	2290.99	48.77	0.00
P012	5828.70	325.40	0.00
P013	2022.91	34.12	0.00
P014	5828.70	325.40	0.00
P015	812.00	48.81	0.00
P016	5016.70	276.59	0.00
P017	5036.70	276.59	0.00
P018	20.00	0.00	0.00
P019	5036.70	276.59	0.00
P020	666.70	200.16	0.00
P021	4370.00	76.43	0.00
P022	484.50	0.00	0.00
P023	182.20	200.16	0.00
P024	171.64	200.16	0.00
P025	10.56	0.00	0.00
P026	6.75	7.91	0.00
P027	164.85	192.25	0.00
P028	76.47	0.00	0.00
P029	88.38	192.25	0.00
P030	75.92	192.25	0.00
P031	12.46	0.00	0.00
P032	74.57	0.00	0.00
P033	1.35	192.25	0.00
P034	1.28	182.52	0.00
P035	0.07	9.73	0.00
P036	157.20	30.73	0.00
P037	1331.09	261.87	0.00
P038	1331.09	261.87	0.00
P039	1200.97	253.96	0.00
P040	130.12	7.91	0.00
P041	281.60	61.79	0.00
P042	919.37	192.17	0.00
P043	130.12	7.91	0.00
P044	123.33	0.00	0.00
P045	0.01	0.03	0.00
P046	2291.00	48.81	0.00
P047	84.00	0.00	0.00
P048	2207.00	48.81	0.00
P049	1395.00	0.00	0.00
P050	1479.00	0.00	0.00
P051	1479.00	0.00	0.00
P052	904.03	0.00	0.00
P053	574.97	0.00	0.00
P054	498.50	0.00	0.00
P055	146.00	0.00	0.00
P056	17.00	0.00	0.00
P057	679.10	11.17	0.00
P058	726.40	16.67	0.00
P059	560.03	0.00	0.00
P060	560.03	0.00	0.00
P061	70.00	0.00	0.00
P062	156.00	0.00	0.00
P063	32.00	0.00	0.00
P064	1893.99	31.14	0.00
P065	4526.00	76.43	0.00
P066	2503.09	42.31	0.00
P067	2573.09	42.31	0.00
P068	2573.09	42.31	0.00
P069	4526.00	76.43	0.00
P070	4370.00	76.43	0.00

P071	24.00	0.00	0.00
P072	39.00	0.00	0.00
P073	116.96	0.00	0.00
P074	234.98	0.00	0.00
P075	234.98	0.00	0.00
P076	157.20	30.73	0.00
P077	157.20	30.73	0.00
P078	157.20	30.73	0.00
P079	41.38	0.00	0.00
P080	198.58	30.73	0.00
P081	198.58	30.73	0.00
P082	1301.42	26.15	0.00
P083	1500.00	56.88	0.00
P084	140.00	0.00	0.00
P085	2667.74	56.88	0.00
P086	1027.74	0.00	0.00
P087	2505.94	50.76	0.00
P088	161.80	6.12	0.00
P089	10.00	0.00	0.00
P090	2525.94	50.76	0.00
P091	10.00	0.00	0.00
P092	1224.52	24.61	0.00
P093	19.70	24.61	0.00
P094	1204.82	0.00	0.00
P095	58.07	72.61	0.00
P096	38.37	48.00	0.00
P097	50.57	0.00	0.00
P098	7.50	72.61	0.00
P099	6.74	0.00	0.00
P100	0.76	72.61	0.00
P101	0.69	66.25	0.00
P102	0.07	6.36	0.00
P103	195.87	35.55	0.00
P104	195.94	41.91	0.00
P105	195.94	41.91	0.00
P106	195.94	41.91	0.00
P107	96.00	14.89	0.00
P108	291.94	56.80	0.00
P109	291.94	56.80	0.00
P110	1.72	0.33	0.00
P111	290.22	56.47	0.00
P112	364.85	56.47	0.00
P113	74.63	0.00	0.00
P114	364.85	56.47	0.00
P115	2400.00	48.22	0.00
P116	2764.85	104.69	0.00
P117	2177.64	0.00	0.00
P118	4942.49	104.69	0.00
P119	194.00	8.47	0.00
P120	4748.49	96.22	0.00
P121	20.00	0.00	0.00
P122	4788.49	96.22	0.00
P123	20.00	0.00	0.00
P124	2388.49	48.00	0.00
P125	2350.12	0.00	0.00
P126	3554.94	0.00	0.00
P127	421.70	0.00	0.00
P128	3976.64	0.00	0.00
P129	3976.60	0.00	0.00
P130	494.97	0.00	0.00

P131	142.00	0.00	0.00
P132	5.00	0.00	0.00
P133	862.52	0.00	0.00
P134	15.00	0.00	0.00
P135	154.98	0.00	0.00
P136	862.52	0.00	0.00
P137	295.00	0.00	0.00
P138	567.52	0.00	0.00
P139	18.00	0.33	0.00
P140	330.00	0.33	0.00
P141	312.00	0.00	0.00
P142	18.00	0.00	0.00
P143	332.00	0.00	0.00
P144	373.80	14.92	0.00
P145	373.80	14.92	0.00
P146	373.70	14.89	0.00
P147	0.10	0.03	0.00
P148	517.70	14.89	0.00
P149	144.00	0.00	0.00
P150	16.28	0.00	0.00
P151	136.60	28.33	0.00
P152	247.83	56.21	0.00
P153	111.23	27.88	0.00
P154	247.83	56.21	0.00
P155	60.00	7.98	0.00
P156	326.00	64.19	0.00
P157	18.17	0.00	0.00
P158	326.00	64.19	0.00
P159	494.84	6.96	0.00
P160	1712.00	95.75	0.00
P161	891.28	24.60	0.00
P162	1224.13	71.08	0.00
P163	487.99	24.67	0.00
P164	30.00	0.00	0.00
P165	1254.13	71.08	0.00
P166	1254.13	71.08	0.00
P167	1039.70	14.61	0.00
P168	214.43	56.47	0.00
P169	166.32	0.00	0.00
P170	48.11	56.47	0.00
P171	43.51	56.47	0.00
P172	4.60	0.00	0.00
P173	0.27	0.33	0.00
P174	43.24	56.14	0.00
P175	15.88	56.14	0.00
P176	27.36	0.00	0.00
P177	85.00	0.00	0.00
P178	15.30	0.00	0.00
P179	0.58	56.14	0.00
P180	0.53	54.63	0.00
P181	0.05	1.51	0.00
P182	277.30	0.00	0.00
P183	765.29	24.67	0.00
P184	765.29	24.67	0.00
P185	0.01	0.07	0.00
P186	765.28	24.60	0.00
P187	126.00	0.00	0.00
P188	544.86	7.65	0.00
P189	224.00	0.00	0.00
P190	10.00	0.00	0.00

P191	779.13	7.98	0.00
P192	719.13	0.00	0.00
P193	885.45	0.00	0.00
P194	166.32	0.00	0.00
P195	885.45	0.00	0.00
P196	9.00	253.09	0.00
P197	1102.88	31.78	0.00
P198	1111.95	294.60	0.00
P199	0.35	0.33	0.00
P200	1111.60	294.27	0.00
P201	275.80	72.65	0.00
P202	835.80	294.27	0.00
P203	617.80	38.99	0.00
P204	4964.24	260.61	0.00
P205	3510.64	0.00	0.00
P206	4964.24	260.61	0.00
P207	3510.64	0.00	0.00
P208	4964.20	260.51	0.00
P209	618.00	39.17	0.00
P210	4346.20	221.34	0.00
P211	1211.20	221.34	0.00
P212	3135.00	0.00	0.00
P213	3135.00	0.00	0.00
P214	375.64	0.00	0.00
P215	1060.23	221.34	0.00
P216	1211.20	221.34	0.00
P217	2884.80	0.00	0.00
P218	1673.60	0.00	0.00
P219	2562.64	0.00	0.00
P220	322.16	221.34	0.00
P221	131.80	221.34	0.00
P222	190.36	0.00	0.00
P223	131.80	221.34	0.00
P224	1060.23	221.34	0.00
P225	928.43	0.00	0.00
P226	150.97	0.00	0.00
P227	1079.40	0.00	0.00
P228	1079.40	0.00	0.00
P229	2753.00	0.00	0.00
P230	190.36	0.00	0.00
P231	2753.00	0.00	0.00
P232	4.26	0.83	0.00
P233	150.88	24.62	0.00
P234	952.00	7.16	0.00
P235	281.11	0.00	0.00
P236	1118.11	0.00	0.00
P237	837.00	0.00	0.00
P238	1393.91	72.65	0.00
P239	1393.91	72.65	0.00
P240	0.01	0.02	0.00
P241	1393.90	72.63	0.00
P242	171.00	10.83	0.00
P243	1222.90	61.79	0.00
P244	385.90	61.79	0.00
P245	837.00	0.00	0.00
P246	385.90	61.79	0.00
P247	810.90	61.79	0.00
P248	425.00	0.00	0.00
P249	90.55	61.79	0.00
P250	720.35	0.00	0.00

P251	720.35	0.00	0.00
P252	28.80	61.79	0.00
P253	61.75	0.00	0.00
P254	782.10	0.00	0.00
P255	357.10	0.00	0.00
P256	357.10	0.00	0.00
P257	252.80	0.00	0.00
P258	104.30	0.00	0.00
P259	28.80	61.79	0.00
P260	281.60	61.79	0.00
P261	281.60	61.79	0.00
P262	261.31	0.00	0.00
P263	261.31	0.00	0.00
P264	1584.29	23.79	0.00
P265	151.86	0.00	0.00
P266	1171.12	23.79	0.00
P267	1438.41	0.00	0.00
P268	145.88	23.79	0.00
P269	1438.41	0.00	0.00
P270	1459.67	0.83	0.00
P271	17.00	0.00	0.00
P272	1454.67	0.00	0.00
P273	5.00	0.83	0.00
P274	1454.67	0.00	0.00
P275	175.00	0.00	0.00
P276	17.00	0.00	0.00
P277	2149.26	31.14	0.00
P278	2149.26	31.14	0.00
P279	104.30	0.00	0.00
P280	671.82	0.00	0.00
P281	671.82	0.00	0.00
P282	118.10	0.00	0.00
P283	38.04	0.00	0.00
P284	82.71	0.00	0.00
P285	1.10	30.80	0.00
P286	119.20	30.80	0.00
P287	119.20	30.80	0.00
P288	609.01	30.80	0.00
P289	489.81	0.00	0.00
P290	609.01	30.80	0.00
P291	0.01	0.01	0.00
P292	609.01	30.80	0.00
P293	489.81	0.00	0.00
P294	565.00	27.88	0.00
P295	111.23	27.88	0.00
P296	451.77	0.00	0.00
P297	489.81	0.00	0.00
P298	0.72	20.60	0.00
P299	83.48	22.11	0.00
P300	0.17	0.17	0.00
P301	83.31	21.94	0.00
P302	403.63	0.00	0.00
P303	802.41	41.82	0.00
P304	315.47	19.88	0.00
P305	802.41	41.82	0.00
P306	802.41	41.82	0.00
P307	0.01	0.02	0.00
P308	703.80	35.55	0.00
P309	98.60	6.25	0.00
P310	315.60	20.00	0.00

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P311     315.60     20.00     0.00
P312       0.13      0.12     0.00
P313     508.00      0.00     0.00
P314     195.80     35.55     0.00
P315     195.80     35.55     0.00
P316     270.70      0.00     0.00
P317     466.50     35.55     0.00
P318     414.40      0.00     0.00
P319      52.10     35.55     0.00
P320      23.70      0.00     0.00
P321      28.40     35.55     0.00
P322      28.40     35.55     0.00
P323     167.47      0.00     0.00
P324     195.87     35.55     0.00
P325      23.70      0.00     0.00
P326     438.10      0.00     0.00
P327     438.10      0.00     0.00
P328     167.40      0.00     0.00
P329     104.37      0.00     0.00
P330     271.77      0.00     0.00
P331     271.77      0.00     0.00
P332     167.47      0.00     0.00
7   OUTPUTS FOR STEADY-STATE FLOW INITIAL RUN
1 001 1
1 002 1
1 003 1
1 004 1
1 005 1
1 006 1
1 007 1
    0.10000    DTIME
  100.00000    DPRT
  200.00000    DMAP
  400.00000    TFINAL

/END CARD READ, JOB TERMINATED
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